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# THE EFFECT OF VARIOUS DIETS ON GROWING PIGS

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In another place we (1) have published the results of experiments on the effect of various diets on the susceptibility of pigs to *Salmonella suipestifer* infection. Briefly, under the conditions of our experiments, conducted in Eastern and Western Canada, the cultures employed were toxigenic and a few pigs died after an actue condition following the administration of culture by mouth, but in no instance did necrotic enteritis develop. The primary object of the experiment was to determine what effect, if any, the various diets would have on susceptibility, and the results of feeding on the growth and development of the animals was only briefly discussed. In this paper our object is to present such feeding data as was obtained and to introduce only such of the other phase of the experiment as is necessary to explain the results. We do wish to emphasize, however, that this is only the by-product of the other work and has no pretension to having been conducted as a feeding experiment. The data may be of some interest on account of the background of the work.

## I. REPLACEMENT OF ANIMAL PROTEIN WHOLLY AND IN PART BY SOYA BEAN OILMEAL

Fifteen pigs about 8 weeks of age were arranged in groups of 3. These animals had been obtained from 2 litters on the same premises and were only 1 day apart in age. They were weaned at 7 weeks. The pigs were so grouped that the total weight of each group was between 61 and 63 lb. They were identified by metal ear tags. Each group had access to a small dirt run which was devoid of all vegetation.

The basal ration employed throughout this experiment consisted of oat chop 40%, wheat and barley chop 30% each, ground limestone 1% and iodized salt 0.5%. When alfalfa or other green feed was unobtainable, and this was usually the case, feeding oil in the recommended amounts was provided daily. The diets for the 5 groups were as follows:—

Group 1. Basal ration and feeding oil.

2. Basal ration, oil and 10% tankage.

3. Basal ration, oil and sufficient soya bean oilmeal to bring the protein to the same level as No. 2.

[1] The first experiment was conducted at the Branch Laboratory, Lethbridge, Alta., and the second and third at the Animal Diseases Research Institute, Hull, Quebec.

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4. Basal ration, oil and sufficient of a 50-50 tankage-oilmeal mixture to maintain the same protein level as groups 2 and 3.
5. Basal ration, oil and a 75-25 tankage-oilmeal mixture to maintain the same protein level as groups 2, 3 and 4.

Soya bean oilmeal contains about 36.5% protein whereas tankage contains not less than 50% so that, in order to have the same amount of protein in each lot, groups 3, 4 and 5 were fed such quantities of the supplements as would allow for the difference in protein of each mixture.

The tankage was cut from 10% to 8% when the average weight of all the hogs was approximately 60 lb. and to 6% when the average weight approximated 100 lb. The other supplements were reduced to maintain the same protein levels as the tankage. They were maintained at the last level until the hogs were marketed.

During the first 168 days of the experiment, the pigs were regularly weighed and a close check was maintained on group feed consumption. The original and final weights, the gain in pounds, the average daily gain of individuals and groups and the feed consumption per pound of gain are shown in Table 1.

TABLE 1.—GAINS AND FEED CONSUMED IN LB. OVER A PERIOD OF 168 DAYS

| Group | Pig | Original weight | Weight 168 days | Gain | Group gain | Gain per pig/day | Group gain per day | Cost per lb. gain in cents for 112 days |
|---|---|---|---|---|---|---|---|---|
| 1 | 932 | 18 | 103 | 83 | 321 | 0.50 | 1.91 | 7.4 |
| | 933 | 28 | 190 | 162 | | 0.96 | | |
| | 937 | 16 | 90 | 74 | | 0.44 | | |
| 2 | 938 | 16 | 203 | 187 | 536 | 1.11 | 3.19 | 6.3 |
| | 939 | 21 | 203 | 182 | | 1.08 | | |
| | 940 | 25 | 192 | 167 | | 0.99 | | |
| 3 | 941 | 23 | 210 | 187 | 546 | 1.11 | 3.25 | 9.8 |
| | 942 | 23 | 224 | 201 | | 1.19 | | |
| | 974 | 16 | 174 | 158 | | 0.94 | | |
| 4 | 975 | 20 | 190 | 170 | 561 | 1.01 | 3.34 | 8.2 |
| | 976 | 25 | 237 | 212 | | 1.26 | | |
| | 977 | 16 | 195 | 179 | | 1.06 | | |
| 5 | 978 | 27 | 233 | 206 | 615 | 1.22 | 3.66 | 8.5 |
| | 979 | 18 | 235 | 217 | | 1.29 | | |
| | 980 | 18 | 210 | 192 | | 1.14 | | |

It will be seen from Table 1 that the largest gains were made by Group 5 which received the 75-25 oilmeal-tankage supplement. However, the cheapest gains were made in group 2 in which tankage alone was employed. The next cheapest gains were in Group 1 on the basal ration, but this group only represented 383 lb. against 598 in the next smallest group. No attempt was made to establish the minimum amount of each concen-

trate required as we were only concerned with having groups receiving no additional protein and sufficient protein to maintain good growth. The cost is based on basal ration $29.45 per ton, feeding oil $3.90 per gallon, tankage $3.50 per cwt. and soya bean oilmeal $9.50 per cwt. The group gains made by each of the supplement groups are relatively close, there being a difference of only 79 lb. between the highest and lowest of these.

While the gains for group 5 were highest at the finish, followed by Groups 4, 3, 2 and 1, this order was not maintained throughout the experiment as is shown by the percentage gain of each group over the original weight at 28-day intervals. This is given in Table 2.

TABLE 2.—PERCENTAGE GAIN OF EACH GROUP AT 28-DAY INTERVALS OVER THE ORIGINAL WEIGHT OF THE GROUP

| Group | Days | | | | | |
|---|---|---|---|---|---|---|
| | 28 | 56 | 84 | 112 | 140 | 168 |
| | % | % | % | % | % | % |
| 1 | 33.4 | 61.3 | 140.3 | 261.3 | 391.9 | 517.7 |
| 2 | 52.1 | 125.8 | 309.7 | 538.7 | 759.7 | 864.5 |
| 3 | 68.6 | 167.7 | 337.1 | 491.1 | 682.3 | 880.6 |
| 4 | 62.4 | 142.6 | 290.2 | 482.0 | 711.4 | 919.7 |
| 5 | 65.1 | 157.1 | 341.3 | 541.3 | 766.7 | 976.2 |

It will be seen from Table 2 that the pigs in Group 3 made the highest gain during the first 56-day period. On the 84th day the greatest gain over the starting weight was recorded for group 5, from which time this group maintained the lead. The lowest gain, as was to be expected, was consistently recorded for Group 1. The second position was held by Group 5 for the first 56-day period, by Group 3 at the 84th day weighing, by Group 2 on the 112th and 140th days and by Group 3 on the 168th day.

There were variations in health prior to and following exposure to infection but, as the infecting doses of *S. suipestifer* were not commenced until the 184th day, the results of these have no bearing on the feeding results. The pre-infection variations, however, do influence the results. On the 32nd day, No. 933 in Group 1 developed respiratory symptoms and loss of appetite; it had recovered again by the 45th day. In spite of the set-back, this animal made better daily gains over the 168-day period than the other two in the group.

On the 46th day, No. 939 in Group 2 was scouring. It was treated and returned to the group in 5 days. No. 979 in Group 5 developed similar but milder symptoms and recovered in 36 hours.

During the period from the 98th to 112th days the food consumption of the pigs in Group 3 fell away greatly. They appeared normal in all other respects but made the smallest gain of any of the 5 groups during this period. The weights of each group for the 2-week periods are shown in Table 3.

TABLE 3.—GAIN IN WEIGHT OF GROUPS 1 TO 5 AT INTERVALS OF 2 WEEKS

| Group | Days | | | | | |
|---|---|---|---|---|---|---|
| | 1 – 14 | 14 – 28 | 28 – 42 | 42 – 56 | 56 – 70 | 70 – 84 |
| | lb. | lb. | lb. | lb. | lb. | lb. |
| 1 | 10.0 | 10.0 | 4.5 | 13.5 | 16.0 | 33.0 |
| 2 | 18.0 | 13.0 | 22.5 | 24.5 | 48.0 | 66.0 |
| 3 | 20.5 | 22.5 | 27.0 | 34.0 | 45.0 | 60.0 |
| 4 | 15.0 | 23.0 | 20.5 | 28.5 | 34.0 | 56.0 |
| 5 | 13.5 | 27.5 | 28.0 | 30.0 | 51.0 | 65.0 |

| Group | Days | | | | | |
|---|---|---|---|---|---|---|
| | 84 – 98 | 98 – 112 | 112 – 126 | 126 – 140 | 140 – 154 | 154 – 168 |
| 1 | 36.0 | 39.0 | 40.0 | 41.0 | 45.0 | 33.0 |
| 2 | 71.0 | 71.0 | 80.0 | 57.0 | 50.0 | 15.0 |
| 3 | 58.0 | 38.0 | 64.0 | 54.0 | 62.0 | 61.0 |
| 4 | 49.0 | 68.0 | 68.0 | 72.0 | 71.0 | 56.0 |
| 5 | 68.0 | 58.0 | 61.0 | 81.0 | 78.0 | 54.0 |

As the experiment approached the 152nd day the food consumption of Group 2 was considerably lower than that of the other groups. On the 154th day, No. 939 in Group 2 again developed diarrhoea and had a temperature of 103.8, which persisted for a couple of days. *S. suipestifer* was recovered from the faeces of this animal. On the 160th day, No. 940 in this group had a slight elevation of temperature and loss of appetite. The hogs in this group had not returned to normal until the 167th day. Feed consumption was approximately 100 lb. less than any of the other groups during the 154–168-day period and this was reflected in the gain for that time. No. 939 gained only 2 lb. and No. 940 neither gained nor lost.

Table 3 further shows that for the first 70 days the greatest bi-weekly gain alternated between Groups 3 and 5. From the 70th to the 126th day Group 2 showed the largest gain. From the 126th to the 154th day Group 5 again showed the highest gain and during the last 2 weeks this position fell to Group 3. With the exception of Group 3 in the 98–112 day period and Group 2 in the 154–168 day period, the lowest bi-weekly group gain was made by Group 1.

Briefly, for the first 168 days of this experiment the highest gains were recorded for Group 5 which received the 75-25 oilmeal-tankage supplement, followed by Groups 4, 3, 2, and 1, which were 50-50 mixture, soya bean oilmeal alone, tankage alone, and no supplement, respectively. For comparable gains, Group 2 (tankage alone) was the most economical and Group 3 (soya bean oilmeal) the most expensive.

## II. BASAL RATION AND VARIOUS SUPPLEMENTS

On April 16, eight groups of 4 pigs each were assembled in a cement-floored, well-lighted stable in pens 10′ × 6′. The pigs had been obtained from 3 sources and had been weaned from 1 to 3 weeks. Care was taken

to have each source represented in a pen so that, as far as possible, the groups would be similar. All were tagged for identification and the males were castrated. These animals were put on various diets with the object of determining whether these would have any effect on the susceptibility of the different groups to infection with *S. suipestifer*. Since this was not in any way intended as a feeding experiment, the only concern being with the effect of diet on susceptibility, the feed was not weighed. The pigs were fed as much as they would clean up in a reasonable time, at first 3 times a day and later twice.

Owing to difficulty in obtaining some of the supplements, these animals received a 40-30-30 mixture of oat, wheat and barley chop until May 11. From that time they received equal parts of oat, wheat and barley chop, 1% of salt and the following supplementary substances:—

Group 1 Basal ration only (Diet A).
2. Basal ration with 1% limestone (Diet B).
3. Basal ration, limestone and 10% tankage (Diet C).
4. Diet C and 5 cc. feeding oil per pig/day (Diet D)
5. Diet D and 1 oz. dried brewers yeast per day.
6. Diet D and 100 mg. of nicotinic acid per pig/day.
7. Diet D and 1.5 grams iron sulphate per pig/day.
8. Diet D with NaOH solution once daily.

The tankage in Groups 3 to 8 was gradually reduced to 5%. Yeast and nicotinic acid were included because so much has been written regarding their use in the prevention and treatment of necrotic enteritis. Iron was used against the possibility of sub-clinical anaemia. It was at first given in capsules but was later incorporated in the feed. Sodium hydroxide was introduced because it had proved to be of value in checking necrotic enteritis under field conditions and it was desired to see whether it would have any preventive value and if it had any harmful effects. Since none of the pigs became infected the former point remained unsettled and, under the latter, there did not appear to be any bad effects, unless a somewhat lower haemoglobin content of the blood could be ascribed to its use. The stock solution consisted of 1 lb. of Gilletts lye in 1 gallon of soft water. One fluid ounce of this was added to 1 gallon of water and one feeding a day was mixed with this solution. Water was used for the other feedings. All groups were fed wet.

The details of this experiment have been reported in the previous paper and need not be repeated here except as necessary to explain what occurred in the various groups. They were all exposed to infection by mouth with 24-hour broth culture of *S. suipestifer* on July 27, August 25 and 31, September 8, 14, 16, 22, and 27. The first dose gave rise to very severe symptoms and 2 pigs died. One of these was in Group 2 and the other in Group 5. The subsequent doses produced little or no effect.

The pigs were weighed on April 19, May 11, July 7, August 10, and between October 18 and 30. The weights of the groups in April, May and October, the average daily gain per pig from April 19 to May 11, and the average daily gain of these animals from May 11 to the end of the experiment in October, are shown in Table 4.

TABLE 4.—WEIGHTS OF GROUPS 1 TO 8 AND AVERAGE DAILY GAIN PER PIG FROM APRIL 19 TO MAY 11 AND MAY 11 UNTIL END OF EXPERIMENT

| Group | Weight | | | Average daily gain per pig | |
|---|---|---|---|---|---|
| | April | May | October | April–May | May–October |
| | lb. | lb. | lb. | lb. | lb. |
| 1 | 109 | 133 | 570 | 0.27 | 0.63 |
| 2* | 75 | 101 | 556 | 0.39 | 0.89 |
| 3 | 113 | 161 | 931 | 0.54 | 1.14 |
| 4 | 86 | 112 | 949 | 0.29 | 1.26 |
| 5* | 69 | 90 | 714 | 0.31 | 1.26 |
| 6 | 110 | 145 | 951 | 0.39 | 1.23 |
| 7 | 137 | 177 | 988 | 0.45 | 1.26 |
| 8 | 109 | 156 | 966 | 0.53 | 1.26 |

* Based on 3 pigs, as 1 in each of these groups died following the first exposure to infection.

During the first 22 days, when the pigs were on a diet of grain only, the average daily gain per pig for the different groups varied from 0.31 to 0.54 lb. This was due to some extent, although not altogether, to the difference in size of the pigs. Roundworms probably played some part. No effort was made to treat the animals as it was desired to leave the worms for the purposes of the experiment. The period from May to October, shows an increased daily gain for the pigs that received the added protein. The addition of yeast, nicotinic acid, iron sulphate and NaOH solution in groups 5, 6, 7, and 8, respectively, made no appreciable difference to the results. Group 3 did not receive feeding oil and was slightly behind the others but this was more noticeable in the smoothness of the pigs than in the daily gains.

Twenty of the surviving 30 pigs were slaughtered, 10 sows being kept for future experimental work in connection with resistance to infection. Necropsies on the 20 animals were performed at time of slaughter. One animal in Group 3 had arthritis in one tarsal joint. There was a history of injury but the condition may have been due to lack of Vitamin A. Twelve animals had roundworms ranging in number from 1 to 75. All were otherwise negative.

### III. CORN WITH AND WITHOUT TANKAGE COMPARED WITH REGULAR DIET

In connection with endeavours to infect pigs with *S. suipestifer* some were put on corn diets. Sixteen pigs were divided in groups of 4 animals each. The first 3 groups were from the same source and feeding was commenced on September 23. The fourth group was introduced on October 2 and these 4 pigs were from a different source than the others. The diets were as follows:—

Group 1. Equal parts oat, wheat and barley chop, tankage 10%, limestone 1%, NaCl 0.5% and 5 cc. feeding oil per pig/day.

2. Corn meal, tankage 10%, limestone 1%, NaCl 0.5% and feeding oil.

3. Corn meal, limestone, NaCl and feeding oil.

4. Corn meal, limestone and NaCl.

Group 4 was added to try the effect of leaving out any outside source of Vitamin A. Richter and Rice (2) have shown that there was loss of appetite and activity in rats on an exclusive corn diet and that these animals scarcely maintained their starting weight. In the case of Group 4 it should be noted that the pigs were obtained from a different source and were not as good as Groups 1 to 3.

In the course of the experiment, the pigs were exposed to infection with *S. suipestifer* by the administration of broth cultures of this organism on 2 occasions and half of them were exposed to sub-zero temperatures for 52 hours. The sudden change from the comparative comfort of the pig stable had no apparent effect on these animals.

These pigs were killed in February. Two animals in Group 4 had non-specific lung and pleural infections but the others were essentially negative. Roundworms varied in number from none to 115. The groups were commenced at 2 different times and were killed at different times in February so that no very exact comparison can be made. However, the weights and average daily gains from commencement to time of slaughter are shown in Table 5.

TABLE 5.—WEIGHTS OF GROUPS AND AVERAGE DAILY GAINS OF PIGS IN EXPERIMENT 3

| Group | Sept. 23 | Oct. 2 | Nov. 2 | Feb. | No. of days | Average daily gain per pig/day |
|---|---|---|---|---|---|---|
| | lb. | lb. | lb. | lb. | | lb. |
| 1 | 111 | – | 202 | 667 | 155 | 0.89 |
| 2 | 132 | – | 200 | 598 | 155 | 0.75 |
| 3 | 129 | – | 159 | 380 | 137 | 0.45 |
| 4 | – | 108 | 92 | 206 | 126 | 0.19 |

The first three groups in Table 5 are strictly comparable as the pigs came from the same source and were commenced at the same time. Group 1 on mixed grain and tankage did better than group 2 on the corn and tankage diet, but the great difference was between these groups and groups 3 and 4. As already pointed out, group 4 was from a different lot of pigs but, even allowing for this, the difference in gains was too great to be merely due to this factor.

## SUMMARY

During the 168-day period recorded in Experiment 1, the highest gains were made by the group on the 75-25 soya bean oilmeal-tankage supplement, followed by the groups which had received 50-50 oilmeal-tankage, soya bean oilmeal alone, tankage alone and no supplement, respectively. For comparable gains, the tankage group was the most economical and the soya bean oilmeal group the most expensive. The differences in the gains of any of the supplement groups was not very large but there was a great difference between these groups and that on the basal ration only. It is generally recognized that a mixture of proteins

is better than a single one, which was borne out in this experiment, although any of the mixtures, apart from cost, might have been satisfactorily employed.

In Experiment 2, the two groups that did not receive any protein supplement were considerably behind the tankage groups. The addition of yeast, nicotinic acid, iron sulphate and sodium hydroxide solution made no noticeable difference to the tankage groups. One group, which received tankage but no feeding oil was slightly behind the others but this was more appreciable in smoothness than in daily gains.

In Experiment 3, in which 1 group received oat, wheat and barley chop and the other 3 corn meal, the best gains were made by the chop, tankage, limestone, salt and oil group, with the corn meal, tankage, limestone, salt and oil group next. There was a considerable drop in the group that had corn meal, limestone, salt and oil, and a very great difference in the group on corn meal, limestone and salt without feeding oil. Unfortunately this last group was from another source than the first 3 groups but the difference in gains appeared to be too great to be attributed to this factor alone.

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# PARTHENOCARPIC FRUIT PRODUCTION IN HORTICULTURAL PLANTS[1]

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The 1942 and 1943 fruit blossoming seasons in many parts of Canada were characterized by cold, rainy weather, and the few sunny periods were cold enough in some districts to restrict the activities of pollinating insects. Recent reports on the artificial induction of seedless fruits in vegetables and ornamentals by Gardner and Marth (1), Gustafson (2, 3, 4, 5), Varrelman (7), and Wong (8), gave rise to speculation as to whether or not plant hormones might be utilized to induce the set of seedless apples, especially during spring periods when natural pollinating conditions were not good.

Briefly, the modern technique of inducing parthenocarpy consists of applying some substance to the female reproductive organs (stigma, style or ovary) of the flower. For a positive reaction, the substance so stimulates the ovary that normal swelling of the ovary and receptacle takes place in the absence of actual fertilization. Natural substances, such as talc and pollen extract, have been used with some success, but the most outstanding results have been secured by Gustafson (2, 4), Howlett (6), Wong (8) and others, using various plant hormone chemicals. These hormone substances (sometimes termed "phytohormones" and "growth substances") are now produced commercially as aids in rooting plant cuttings, and preventing pre-harvest fruit drop. The chemicals most used for such purposes have been such acids as indoleacetic, indolebutyric, indolepropionic, naphthaleneacetic and phenylacetic. In addition, salts and acetamides of some of these acids have been found to be active as plant hormones. A new compound, naphthoxyacetic acid, has been shown to be quite active for inducing parthenocarpy (4), but a supply could not be secured for the work reported here.

The hormones may be applied to the flower parts in solution (as sprays) or in paste form combined with a non-injurious carrier such as lanolin (sheep's wool fat). In addition to these commonest methods, hormones have sometimes been injected into the flower ovary, or vaporized in a tight compartment where the plants are growing (9).

## MATERIALS AND METHODS

Preliminary trials to note the effect of indolebutyric acid (I A)[3] and naphthaleneacetic acid (N A)[3] on petunia, potatoes and tomatoes, were conducted under glass during the winter and spring of 1943. Lanolin paste and aqueous solutions of the materials were used at varying concentrations. The paste was applied to stigmas, to the ovary apex where style has been broken out, to the base of individual flowers, and to the

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[3] These abbreviations will be used hereinafter.

cluster base in plants having flowers borne in clusters. Almost all flowers were emasculated in the bud stage, and treatments were made from one to three days later, usually when the stigmas were in a receptive condition.

For outdoor trials, apple flowers alone were used, and for all treatments except the power-spraying of entire trees, the individual flowers were emasculated and in most cases the clusters were bagged to prevent the intrusion of any pollen or aphis stimulus.

## RESULTS

*Petunia*

Sixty flowers were treated either at the ovary, the stigma or the flower base. Twenty-two fruits, seedless, and varying from 35% to 50% of normal size, were harvested. Ovary applications of either NA or IA with lanolin as a paste carrier were the most successful treatments. Concentrations of hormones thus successfully used were from 0.1% to 5.0%. Flowers sprayed with NA 1.0% were quickly killed. Flowers pollinated with another petunia variety produced normally seeded fruits, but the wrinkled parthenocarpic fruits induced with hormones were filled with minute, empty seed coats.

*Potatoes*

Of 134 Earlaine potato flowers treated with hormones, only 7 seedless fruits were produced. These were about one-third normal size, and contained no seeds. Their locules were filled solidly with pulp. Applications of NA (1.0% and 5.0%) lanolin paste produced the 7 parthenocarpic fruits, and the use of IA and NA at lower concentrations on the ovary, or from 0.05% to 5.0% on the stigma, produced negative results. Similarly, no fruits were induced by using NA as a spray (0.01% and 1.0%) on emasculated flowers, or by using several concentrations of NA and IA in lanolin paste at the base of flower clusters. Crossings and selfiings involved 33 flowers, and resulted in 10 normally-seeded fruits.

On Katahdin potato variety, 207 blossoms were treated, with only 11 seedless fruits resulting. From 31 crossings and selfings 4 normally-seeded fruits were obtained. As on the Earlaine variety, treatments of flowers at the cluster base with lanolin paste, or by spraying, induced no seedless fruits. Applications of paste at concentrations lower than NA 1.0% gave negative results, except where the base of the flower were treated, when 0.1% NA lanolin paste induced 6 very small fruits, all borne on one cluster. These fruits were only one-thirtieth as large as normally-seeded fruits, and only one-tenth as large as the other seedless fruits obtained.

*Tomatoes*

Results with hormone treatment of 384 flowers of Earliana, V121 and Vetomold tomato varieties were much more positive than those obtained by similar treatments on the closely related potato plants. The treatment of 58 ovaries with NA and IA lanolin paste at concentrations ranging from 0.025% to 5.0% resulted in 39 seedless fruits. Treatment of 87 stigmas with the same range of pastes induced 53 seedless fruits.

The cluster base treatments (NA paste 0.05% to 2.5%) involved 47 unemasculated flowers. Only 5 seedless fruits resulted, but 38 normally-seeded fruits were borne on the treated clusters.

Tomato flowers sprayed with NA concentrations from 0.005% to 0.25% resulted in 97 seedless fruits from 208 treated flowers. These flowers were emasculated a few days before being treated. At least 2 sprays were made, at intervals of 2 days. The higher concentrations gave as many seedless fruits as the lower, but they were smaller and much more warped and injured by the spray, as was also any foliage that was touched by the stronger sprays.

The seedless tomatoes induced by hormone treatments were rather small. In fact, 54% were classed as 1 inch or smaller in equatorial diameter, 22% were between 1 and 2 inches, and 24% were 2 inches or over.

The effective range of plant hormone concentration in inducing seedless tomatoes was very wide, as it was also for petunia. Combined with lanolin to form a paste, the range was from 0.01% to 5.0%, although concentrations of 0.5% to 5.0% injured the fruit and pedicel to varying degrees. Spray concentrations on tomatoes were effective from 0.005% to 0.25%, but again the high concentration (0.1% to 0.25%) caused injury. Severe epinasty occurred on the foliage when the clusters were sprayed with the higher concentrations, and the seedless fruit borne on these clusters was dwarfed and rough.

The majority of the seedless tomatoes contained very small seed initials or (in a few cases) normal-sized empty seed coats. A few had solid-fleshed locules, but in most the locules were filled with soft gelatinous substance.

*Apples*

In addition to entire trees that were power-sprayed with hormone solutions, 3,293 individual flowers (from 5 varieties) were treated with NA in lanolin paste and hand-sprayed solutions. Most of the treated flowers were emasculated in the pink bud stage, and groups of 2 to 5 clusters of flowers were bagged with brown paper bags. These bags were left on until July 2, full bloom and treatment being on June 8 and 9.

Only 1 seedless fruit was borne on a treated flower, but this was on a variety of *Pyrus malus var. apetala*, and the fruit of this tree is normally seedless. Therefore it is doubtful if the treatment had any effect. Gustafson (5) had slightly better success, for when he treated nearly 1,000 apple bossoms, he obtained 3 lop-sided seedless fruits. Gardner and Marth (1) and Varrelman (7) each report no success in inducing parthenocarpic apples with hormones.

NA spray solutions stronger than 0.05% killed the bagged twigs by Sept. 21, but paste applications, up to 1.0% NA, did not kill back the treated spurs or twigs. In common with clusters treated by spraying, those treated with paste retained their dead blossoms throughout the growing season until early winter. The failure of hormone treated flowers to abscise is a well-known attribute of all the active hormone chemicals.

When entire trees were power-sprayed at full bloom on June 8, no seedless fruits resulted. Concentrations of NA 0.001% killed or incapacitated much of the bloom and a light to very light set of normally-seeded fruit resulted. Higher concentrations (0.005%) rendered the set even lighter or reduced it to zero, and the single tree sprayed with NA 0.01% had no fruit whatever, but the dead blossoms were still adhering late in the autumn. On this tree, too, the foliage showed much more injury than on those sprayed with lower concentrations of NA, but the foliage had recovered completely by the end of the season.

## CONCLUSIONS

The main purpose of this trial was to obtain information on the possibilities of using plant hormones to increase the set of apples in seasons when pollination conditions are poor. It was also hoped that seedless apples could be produced, and that these would have a fairly solid core that would be commercially acceptable, as with seedless grapes and navel oranges. In the light of the results on potatoes, petunia and tomatoes, where the seedless fruits produced were smaller than normal and frequently badly distorted in form, and also because it is well known that parthenocarpic apples induced by aphis clusters on the blossoming spurs are small and irregular, it is questionable whether artificially induced seedless apples would be of value commercially. However, experimental results reported here were negative as far as apples are concerned, although results with petunia and tomatoes were positive, and seedless fruits were easily induced.

No experimental work has hitherto been reported on parthenocarpy in potatoes, but in view of the close botanical relationship between potato and tomato plants, it is somewhat surprising that so little effect was secured by hormone treatment of potato blossoms, whereas the induction of parthenocarpic tomatoes presented no difficulty. The physiological or genetic incompatibility usually found in attempts to obtain seed balls by crossing or selfing commercial potato varieties may have a bearing on this result.

It is possible that new hormone substances, such as naphthoxyacetic acid, might be effective as parthenocarpy inductors on tree fruits, where naphthaleneacetic acid has failed.

## SUMMARY

Parthenocarpic (seedless) fruits were easily induced artificially with plant hormone chemicals on petunia and tomato flowers. On potato flowers the results were not so effective, and on over 3,000 apple blossoms the treatments produced negative results. Concentrations of naphthaleneacetic acid and indolebutyric acid were found to be effective over a wide range on tomato and petunia flowers. For naphthaleneacetic acid this range for lanolin paste was 0.01% to 5.0% and for spray solutions, 0.005% to 0.25%.

In an attempt to induce a set of seedless apples in a season when conditions were unsatisfactory for natural pollination, it was concluded that the use of naphthaleneacetic acid is completely ineffective.

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# A STUDY OF THE CODLING MOTH AND ITS PARASITES IN CALIFORNIA

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Codling moth control has, for some years, been recognized as a problem of increasing difficulty in all parts of North America. As part of a program of control, the Division of Entomology of the Dominion Department of Agriculture, working through the Dominion Parasite Laboratory at Belleville, has introduced into Canada from France, two parasites which were found during investigations conducted on the biological control of this insect in Southern France in 1939 and 1940. In the 1941 season, a survey for parasites of the codling moth was made in California, since reference to literature suggested that this area might be expected to provide a richer fauna than any other section of North America, and would probably show also an exceptionally high degree of control of an introduced pest by native parasites and predators. Some data collected during this survey are given in this report.

## SEASONAL HISTORY AND STATUS OF CODLING MOTH IN CALIFORNIA

First established in California on apples and pears about 1872 (Essig, 12), the codling moth has become since 1918, the major pest of walnuts, and in 1929 was recorded as maintaining itself in parts of S. California on other stone fruits such as plums, apricots and cherries independently of its usual hosts (Smith, 25). There has been much discussion of, and some work done on the question of the relation of the apple infesting codling moth to the so-called "walnut codling moth." It is known that in parts of California the species has been a severe pest of apples and pears since 1880, whereas walnuts in the same districts did not suffer infestations until 1931 (Boyce, 5). It appears probable that there is a "host-determined" race on walnuts, but it has not been proved that it is a distinct genetic race (Smith, 24).

Generally speaking, there are two well defined broods (of moths?) throughout the state, while a partial third is not uncommon in some of the warmer areas. However, demarcation of the latter broods is very difficult because of overlapping. Emergence of moths from the hibernating material commences about mid April and continues through May and June, with the main peak of emergence usually in the latter part of May. Delimitation of the end of the second brood is difficult but is regarded as falling in the last half of August. In the coastal regions there is often low uninterrupted emergence through July, August and September. A small percentage of the mature worms spinning up during the earlier summer months remain in this stage until the following spring.

The codling moth problem, though serious, is probably not yet as serious a problem in California as it is in some other sections of North America. Dr. Macleod (19), of the University of California, Berkeley, has

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stated that the general trend of codling moth populations in Californian orchards is upward, with all indications suggesting that eventually the position will be similar to those parts of the country where from 6 to 12 cover sprays are necessary for fruit protection. At present control methods consist mainly of insecticidal programs which vary with the type of host, though there is some recognition of the importance of sanitary practices. For apples and pears the general practice is to follow the University recommendation of a calyx spray of 4 lb. of standard lead arsenate when 50 to 70% of the petals are off, followed by a second calyx spray within 10 days from the start of the first. All subsequent sprayings, frequently 4 or 5, and in some areas such as Yucaipa 7 or 8, are timed by the bait pan method devised by Borden (4), and these applications are made within a 10-day limit from the beginning of each major peak of emergence. However, the writer has talked to some growers who maintain an arbitrary fortnightly spray program throughout the season, while other growers, usually supply-the local markets and cider industries, bear the losses and have no spray or other control practices.

With walnuts, the other major host of codling moth in California, one thorough properly timed spray of basic lead arsenate generally gives satisfactory control for the season—a somewhat striking contrast to the position with apples. Recently, the increasing importance of the pest all over the state has led to experiments by the University with two treatments in a season. Infestations on other stone fruit hosts of the moth are usually treated with one or two spray applications.

## INVESTIGATIONS

### *Areas Investigated for Parasites*

The apple, pear, and walnut growing areas of the state of California cover a wide range of ecological conditions, and the selection of districts for the study of parasites was determined by four main considerations. Firstly, there was the occurrence of the three broad climatic zones into which the state is divided by horticulturists. These three belts are the Coastal, Valley and Mountain, with the so-called Foothill zone considered as a modification of the Valley type of climate. These general divisions are endorsed by Bowie (Climatic Summary of the United States, Section 16, U.S.D.A. Weather Bureau, 1934,) who points out that the terms "southern," "northern" etc., do not apply to the various sections of California because of such factors as the north-south deflection of the isotherms: and he agrees that a more appropriate classification of the climate is that adopted by horticulturists.

The second consideration in the selection of sampling localities was the distribution in the state of the chief host plants of the codling moth, namely, apple and walnut. Reference to an outline map of California showing the apple acreage by counties, indicated that two-thirds of the total acreage is in the northern coastal counties of Sonoma, Santa Cruz, and Monterey, the remaining third being scattered throughout the Central Valley, foothills and mountains. No maps on the walnut acreage are available, but figures in the annual reports of the California Walnut Growers' Association show that this is concentrated in Southern California,

particularly in the coastal counties of Ventura and Los Angeles. In recent years, however, Valley counties such as San Joaquin have attained crop productions second only to those of Ventura County. There is, of course, only a very limited cultivation of walnuts at the higher altitudes in the mountains.

Thirdly, there was the question of the availability, within these major and minor host plant areas, of orchards which had received little or no insecticidal treatments for codling moth for periods of at least two years preceding the 1941 season. This choice of untreated orchards was considered desirable on general principles as being likely to give conditions more favourable for the activities of any native parasites and predators.

Fourthly, published records of parasites and predators of codling moth in California gave some indication of their distribution in the state.

A fifth, and important non-biological consideration was the amount of money available for covering the labour and travelling expenses over the widely separated parts of the state.

On the basis of the above points the districts shown on page 460 were selected for investigation, and the location of the sampling stations and the apple and walnut areas are shown in a general map of California (Figure I).

Attention was concentrated on the larval and pupal parasites and predators of the codling moth as it was not practicable to make a study of the egg parasites in the various sections owing to the large amount of time involved in locating reasonable numbers of host eggs. Records of parasitism and predatism were obtained chiefly by examination of burlap bands, which were placed either one per tree near the ground level, or one per main branch above the crotch. These bands were made from burlap strips one foot wide, folded 4 thicknesses to form a 3-inch band in order to ensure the exclusion of light. This trapping of mature larvae was supplemented in some orchards by collections of worms by the scraping of bark and the opening of apples, etc. There are, of course, some obvious drawbacks in this banding technique: the heavy mortality of the larvae when they are forced to spin a second cocoon in corrugated paper strips, and the probable inaccessibility of a large percentage of the larvae to attack by any parasites, are the more important of these. There is the further possibility that the concentration of the hosts within these bands provides unusually favourable conditions for the predators so that the value of the latter receives disproportionate emphasis. For example, the writer has found as many as 30 Raphidiid larvae working in one band in orchards in the foothills at Auburn, and it is unlikely that the resulting wholesale destruction of codling moth larvae is at all representative of the position in the orchards.

*Larval and Pupal Parasitism in the 1941–42 Season.*

An indication of the extent of the parasitism of the codling moth larvae and pupae throughout the state can be obtained by an examination of Tables 1, 2, and 3. These data refer only to host material collected from tree bands, and at the time of the summer collection about 33% of the larvae had pupated. It was only possible to make a few observations

on the overwintering larvae of the 1940–41 winter, the data being secured by the co-operation of growers who had banded their trees as part of a control program. The orchard at Little Rock had been sprayed annually for many years and observations in the district were not continued because of failure to locate a suitable unsprayed plot. The town lies on the west edge of the Mojave Desert at an elevation of approximately 3,000 ft. above sea level and has a climate characterized by high summer temperatures.

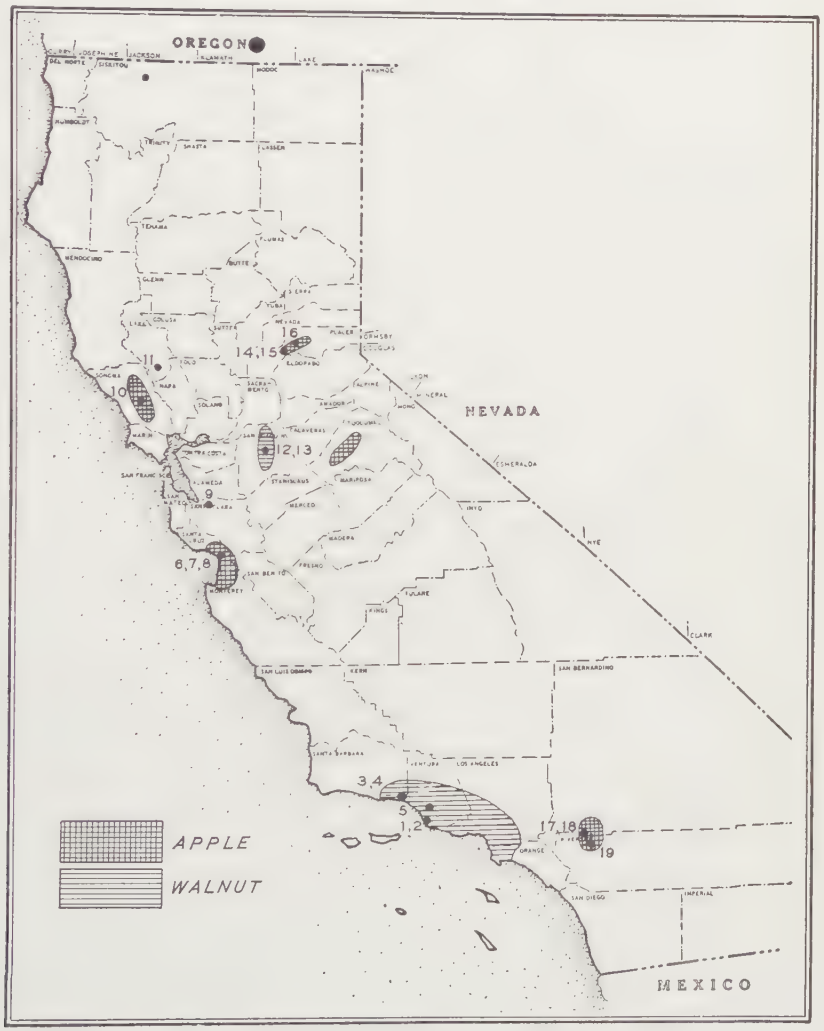


FIGURE 1. Map of the State of California, U.S.A., showing the location of sampling stations and the apple and walnut areas.

All the species listed in the tables were primary, but *Dibrachys cavus* Walk. also developed as a secondary on *Ascogaster quadridentatus* Wesm. = (*carpocapsae* Vier.). The figures for the external and internal parasitism of the summer generation are based on an examination of, and emergence

LOCATION OF SAMPLING STATIONS

| Climatic Zone | District | Elevation | Orchard | Previous spray treatment | No. of trees banded exmnd. |
|---|---|---|---|---|---|
| Coastal | Saticoy | 150 ft. | (1) Walnut. Lloyd. | Annual spray | 100 |
| | | | (2) Walnut. Saticoy citrus | Annual spray | 100 |
| | Carpinteria | 40 ft. | (3) Walnut. Edwards. | Annual spray | 100 |
| | | | (4) Walnut. General ass. | None for years | 30 |
| | Kasitas | 1,000 ft. | (5) Apple. Anderson | None for 10 yrs. | 24 |
| | Watsonville | 30–70 ft. | (6) Apple. Brock. | None for 2 years | 100 |
| | | | (7) Apple. Hill | None for years | 100 |
| | | | (8) Apple. Earle | Annual until 1941 | 100 |
| | San José | 30 ft. | (9) Apple. ? | None until 1941 | 24 |
| | Graton | 190 ft. | (10) Apple. Olman | None for 2 years | 50 |
| | Lower Lake | 1,300 ft. | (11) Apple. Willson | None for years | 20 |
| Valley | Linden | 40 ft. | (12) Walnut. Meier | None for years | 24 |
| | | | (13) Walnut. Carroll | None until 1941 | 40 |
| Foothills | Auburn | 1,200 ft. | (14) Pear. Crockett | None for years | 30 |
| | | 1,800 ft. | (15) Apple. Simpson | None for years | 60 |
| | Colefax | 2,500 ft. | (16) Apple. Rolph | None for 2 years | 40 |
| Mountain | | 3,000 ft. | (17) Apple. Webster | None for 10 yrs. | 100 |
| | | 3,500 ft. | (18) Apple. Parrish | None for 3 yrs. | 70 |
| | Arrowhead | 5,000 ft. | (19) Apple. Davis | None for years | 40 |

from, all hosts collected. With the hibernating material, the external parasitism is based on the total sample collected and that of the internal parasitism on the emergence of adults in the following spring. There was a heavy mortality in the overwintering larvae but this is apparently usual for the host and due in part to the disturbance of the winter cocoons.

Not represented in the tables are supplementary collections of worms from host fruits, etc. in some of the orchards. These gave the following results, largely substantiating those of the band examinations.

TABLE 1.—PARASITISM OF OVERWINTERING CODLING MOTH LARVAE 1940–41

| District | Orchard | Size of sample | Total emergence from sample | *Ascogaster carpocapsae* | *Aenoplex carpocapsae* | *Aenoplex retulae-colae* | *Lixophaga orbitalis* | *Achaetopsis tortricis* | Total external parasitism | Total internal parasitism |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. Carpinteria | Walnut | 397 | 189 (47%) | – | 5 | – | 8 | 1 | 1.2% | 4.7% |
| 2. Watsonville | Apple | 667 | 452 (68%) | 97 | 12 | 3 | – | – | 2.2% | 21.2% |
| 3. Little Rock | Pear | 717 | 276*(39%) | – | 8 | – | – | – | 1.1% | 0 |
| | | 1781 | 917 (52%) | 97 | 25 | 3 | 8 | 1 | 1.5% | 11.5% |

* Cocoons taken from naphthol treated bands.

Summer brood larvae:

*(a)* $1\frac{1}{2}$ tons of wormy, blighty walnuts, collected in late June and early July from two orchards in the Saticoy area, were placed in a large room in the Citrus Experiment Station. The only emergents were thousands of moths.

*(b)* 400 wormy nuts, collected August 10th, from a third grove in Saticoy showed no parasitism though the walnuts selected were those with good exposures of the burrows for the action of any parasites such as *Calliephialtes nucicola* Cushm.

*(c)* In early July a sample of 100 wormy apples at Kasitas Pass had 4% of the codling moth larvae parasitized by *Lixophaga orbitalis* Aldr.

*(d)* In early August 250 wormy apples from Lower Lake had 7 of the host larvae parasitized by *Macrocentrus ancylivorus* Rohw.

*(e)* A sample of 200 wormy apples from Yucaipa (Webster) had all the summer brood hosts unparasitized.

*(f)* 10 to 12 acres of apple trees in 5 orchards in the Watsonville area were banded with corrugated paper in the summer of 1941 and the bands with summer brood larvae were sent down to Riverside for mass emergence in the insectaries. Parasite emergence was very small and the specimens recovered were the same species as those noted in the detailed examinations.

TABLE 2.—PARASITISM OF FIRSTBROOD SUMMER LARVAE IN CALIFORNIA (JULY 1941)

| Orchard | Sample | *Ascogaster carpocapsae* | *Aenoplex carpocapsae* | *Aenoplex betulaecola* | *Lixophaga orbitalis* | *Anachaetopsis tortricis* | *Ephialtes sanguinipes* | *Ischnus* n. sp. | *Macrocentrus ancylivorus* | *Dibrachys cavus* | Total external parasitism | Total internal parasitism |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 160 | – | – | – | – | – | – | – | – | 1 | 0.5% | 0 |
| 2 | 150 | – | – | – | – | – | – | – | – | 1 | 0.6% | 0 |
| 3 | 100 | – | – | – | 3 | – | – | – | – | 2 | 2.0% | 3.0% |
| 4 | None | | | | | | | | | | | |
| 5 | 80 | – | – | – | 10 | – | – | 1 | – | – | 0 | 13% |
| 6 | 150 | 28 | – | – | – | – | – | – | – | 3 | 2.0% | 17% |
| 7 | 50 | 1 | – | – | – | – | – | – | – | – | 0 | 2.0% |
| 8 | 300 | 22 | 7 | 2 | – | – | 1 | – | – | 4 | 4.3% | 8.6% |
| 9 | 200 | 11 | – | – | 23 | – | – | – | – | 2 | 1.0% | 17% |
| 10 | 500 | 78 | – | – | 6 | – | – | – | – | – | 0 | 16.8% |
| 11 | 250 | 1 | – | – | – | – | – | – | 8 | – | 0 | 3.6% |
| 12 | None | | | | | | | | | | | |
| 13 | 150 | – | – | – | 21 | – | – | – | – | – | 0 | 14% |
| 14 | 250 | – | – | – | 6 | – | – | – | – | – | 0 | 2.4% |
| 15 | 400 | – | – | – | 6 | – | – | – | – | – | 0 | 1.5% |
| 16 | 250 | – | – | – | 7 | – | – | – | – | – | 0 | 2.8% |
| 17 | 402 | – | 1 | – | 3 | – | 2 | – | – | – | 0.7% | 0.7% |
| 18 | 461 | 1 | – | – | 1 | – | – | 3 | – | – | 0.2% | 0.9% |
| 19 | 86 | – | – | – | – | – | – | – | – | – | 0 | 0 |
| Totals | 3939 | 142(3.5%) | 8(0.2%) | 2 | 86(2.2%) | 0 | 3 | 4 | 8 | 13 | 0.6% | 6.3% |

TABLE 3.—PARASITISM* OF OVERWINTERING LARVAE (1941–42) IN CALIFORNIA (NOV. 1941)

| Orchard | Sample | Total emergence from sample | *Ascogaster carpocapsae* | *Aenoplex carpocapsae* | *Aenoplex betulaecola* | *Lixophaga orbitalis* | *Anachaetopsis tortricis* | *Ephialtes sanguinipes* | *Ischnus* n. sp. | *Macrocentrus ancylivorus* | *Dibrachys cavus* | Total external parasitism | Total internal parasitism |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 200 | 122(61%) | – | 1 | – | 1 | – | – | – | – | – | 0.5% | 0.8% |
| 2 | 412 | 203(51%) | – | 12 | – | – | – | – | – | – | – | 2.9% | 0 |
| 3 | 400 | 220(55%) | – | 6 | – | 4 | – | – | – | – | – | 1.5% | 1.8% |
| 4 | 155 | 108(60%) | – | 24 | – | 3 | – | – | – | – | – | 9.4% | 2.7% |
| 5 | 188 | 87(46%) | – | 1 | – | 1 | – | – | – | – | – | 0.5% | 0.8% |
| 6 | 1805 | 902(50%) | 142 | – | – | – | – | – | – | – | – | 0 | 15.5% |
| 7 | 392 | 199(51%) | 2 | 11 | – | – | – | – | – | – | – | 2.8% | 1.0% |
| 8 | 3080 | 1600(52%) | 152 | 7 | – | 1 | – | – | – | – | – | 0.2% | 9.5% |
| 9 | 604 | 225(42%) | 12 | – | 1 | 15 | 2 | – | – | – | – | 0.1% | 11.4% |
| 10 | 904 | 514(57%) | 122 | – | – | – | – | – | – | – | – | 0 | 23.7% |
| 11 | 314 | 258(82%) | 1 | 2 | 2 | – | – | – | – | 1 | – | 1.3% | 0.7% |
| 12 | 156 | 86(55%) | – | – | – | 6 | – | – | – | – | – | 0 | 7.0% |
| 13 | 1240 | 730(58%) | – | – | – | 29 | – | – | – | 1 | – | 0 | 4.1% |
| 14 | 43 | 31(72%) | – | – | – | – | – | – | – | – | – | 0 | 0 |
| 15 | 482 | 309(64%) | – | – | – | 3 | – | – | – | – | – | 0 | 1.0% |
| 16 | 744 | 434(58%) | – | 1 | – | 18 | – | – | 1 | – | – | 0.1% | 4.2% |
| 17 | 1902 | 1243(65%) | 14 | 6 | – | – | – | 2 | – | – | – | 0.3% | 0.8% |
| 18 | 2542 | 1552(60%) | 9 | 3 | – | 6 | – | – | – | – | – | 0.1% | 1.0% |
| 19 | 679 | 471(69%) | – | 5 | – | – | – | – | – | – | – | 0.7% | 0 |
| Totals | 16242 | 9294(57%) | 454(4.8%) | 79(0.9%) | 3 | 87(0.9%) | 2 | 2 | 1 | 2 | 0 | 0.9% | 5.8% |

Winter brood larvae:

*(a)* In late September 1941, 1,100 affected walnuts at a Linden grove were opened for worms and 160 found. No parasites were seen.

*(b)* In May 1941, a thorough examination was made of moth emergence cages containing an estimated 15,000 overwintering larvae in bands which had been obtained for Dr. Boyce of the Citrus Experiment Station by the Puente Walnut Growers' Association (S. California, near Los Angeles). No parasites were found although no external parasites were expected in view of the method of collection.

*(c)* Several thousand of the 1941–42 hibernating larvae from bands in the Yucaipa and Watsonville areas were given to Dr. Boyce of the C. E. S. for experiments on the walnut and apple race question. A cursory examination of this material was made, and there is no reason to believe that the parasitism differed from that of the samples taken from the same orchards and shown in the table.

*(d)* Between January and March 1942, collections of at least 25,000 overwintering larvae were obtained from numerous walnut groves under the Saticoy Walnut Growers' Association. With the generous co-operation of Mr. Barrett, entomologist to the Association, large numbers of worms and cocoons being removed from the bands by the team of workers employed by the Association were thrown into tins containing corrugated paper rolls. The material was then forwarded to Belleville; emergence details are not yet available.

It is apparent from inspection of the tables and the above data that the overall controlling effect of the native larval and pupal parasites in the state as a whole is very small. The only species of *any* consequence are *Ascogaster quadridentatus*, *Aenoplex carpocapsae* Cushm. and *Lixophaga orbitalis*. *Ascogaster* was the predominant species in the summer and winter, and is, of course, an introduction on the West coast. Even this species was of sporadic distribution and somewhat low incidence showing a 3.5% parasitism of the summer brood larvae and 4.8% of the overwintering brood. This figure of 4.8% parasitism by *Ascogaster* is undoubtedly much lower than the actual since there was a very heavy mortality of the hosts containing *Ascogaster* larvae. Thus in the areas where *Ascogaster* was observed some 11,543 hibernating codling moth larvae were collected, and examination revealed that 2,593 (22.4%) of these were of the very small size characteristic of those parasitised by this species. The numbers of such small larvae in any collection is a reasonably reliable guide for the parasitism by *Ascogaster*, and on this basis, 41.7% of the Watsonville material and 33.5% of the Graton material, were parasitised by this species.

Summer records show that the species was confined to the coastal zones of Watsonville, San José, Graton and Lower Lake, while the larger winter samples indicated its presence in the Mountain zone of Yucaipa; it was not obtained in the hot Central Valley and the Foothills. It is also interesting to note that it was taken only in the apple orchards though it has been liberated in walnut districts such as Saticoy.

Even with the lower parasitism figures for *Ascogaster*, the figures for the most prevalent native western parasites, *Aenoplex carpocapsae* and *Lixophaga orbitalis*, do not compare too favourably. The Tachinid was present in all climatic zones in apple and walnut orchards, and effected a summer parasitism of 2.2% and winter parasitism of 0.9% for the state. There were several orchards where the summer collections showed up to 14% parasitism by the species, but it may well be that these early summer brood hosts were more heavily parasitised than the later (that is, the small samples probably were not representative of the conditions). *Aenoplex carpocapsae*, the solitary external Ichneumonid parasite on spun-up larvae, appeared of no consequence in the summer brood and its incidence in the collections at this time was easily exceeded in the small winter samples of April 1941. The species was more abundant in the autumn of 1941, and there was a parasitism of 0.9% for the state in early November. This figure may be a little on the low side as it is known that *Aenoplex* is active in some regions in late autumn and early winter. Apart from one specimen from the orchard at an elevation of 2,500 ft. in the Foothills, this species, like *Ascogaster*, was not recovered in the Central Valley and Foothills, but did occur in walnut groves.

The remainder of the native species obtained in the survey seem to be casual parasites of the codling moth. The *Macrocentrus ancylivorus* has been introduced into Washington and Oregon, and has spread into the extreme north of California.

No important differences in the native parasite fauna of the codling moth in regard to host plants and climatic zones were revealed by the survey. Minor differences have been noted in the preceding paragraphs.

*Predators*

No quantitative work on the predators of the codling moth larvae and pupae was attempted. The larvae of *Cymatodera ovipennis* Lec. and *Cymatodera* sp. (Coleoptera, Cleridae) were active in the bands throughout the winter; and *Hydnocera scabra* Lec. (Coleoptera, Cleridae) was noted in several walnut orchards and in some of the apple orchards in the Foothills. A Raphidiid larva, which the United States Natural Museum was unable to identify, was general throughout the area sampled. Unsuccessful attempts were made to rear this latter species through to the adult stage.

The destruction in the bands of spun-up codling moth larvae and pupae by this Raphidiid and the *Cymatodera* spp. was impressive in some orchards, but it has been pointed out previously that the concentration of hosts within the bands may have given an exaggerated importance to this mortality factor. However, on the basis of somewhat cursory visual inspections and without making exact counts, it was evident that the above predators of the codling moth were frequently producing a heavier mortality than that caused by the larval and pupal parasites in the bands.

*Notes on the parasites*

(i) *Aenoplex carpocapsae* Cushm.

Apparently this species, and occasionally a few other members of the same genus, are the only solitary external parasites attacking the codling moth larvae within the cocoon in California. The number of generations

in the season is not well defined, but in most districts there are at least two. Adult parasites emerge from the overwintering cocoons several weeks before peak emergences of the moths, and deposit their eggs on some of the more retarded codling moth larvae in the winter cocoons, and later, on the first summer brood larvae. Throughout the months of July and August, and early September, the majority of these specimens go into a diapause as mature larvae in the cocoons. This diapause occurred also in some laboratory experiments in the early summer of 1941. The small numbers of this species which were found in the field in the summer of 1941 suggest, however, that the parasite may also utilize an alternate host (or hosts) between the spring and September, in which month the larvae transform. The resulting females actively attack the fresh hibernating *Carpocapsa* larvae. Development of the parasite larvae in these hosts proceeds slowly, and while a proportion of them probably transform and start a partial third generation, the majority remain as mature larvae throughout the winter. There is no rigid diapause, however, since the species has been seen by the writer in first, second, and fourth larval, pupal, and adult stages, in various walnut orchards in the coastal county of Ventura in January, one of the coldest months in California; while in March the species was seen as early larvae and as mature larvae in cocoons in an apple orchard at Yucaipa, which has an elevation of 3,500 feet above sea level.

It appears quite definite from the results of the present survey that this parasite is most active on codling moth during the autumn and winter months and this confirms previous observations. Flanders (15) remarked that the *Aenoplex* spp. in the Ventura area attacked the hibernating larvae and were most active during October and November; and Strong (26) states that studies of the cocoon parasite *Aenoplex carpocapsae* showed that breeding nearly ceases during July and August but becomes normal again in September. After being quite abundant in certain orchards in southeastern Illinois in 1935, this species virtually disappeared from the same orchards in 1936.

In the course of laboratory experiments on host selection, a few observations were made on the biology of the parasite. Mating occurs very soon after the emergence from the cocoon, and lasts for 30 seconds or less. Copulation of the sexes seems to be more easily effected by confining 3 or 4 day old males with freshly emerged females in small vials. Males are able to copulate several times in life. Oviposition commences the day after mating so that the pre-oviposition period is probably between 12 and 24 hours. The codling moth larva is first paralyzed and the egg is deposited on any part of the host, or occasionally at any point within the cocoon. Females were never seen to paralyze or oviposit on codling moth pupae. Oviposition by the parasite was better when the females were supplied with the normal cocoons (either scattered loosely on the floor of the cages or gummed on strips of stiff paper) rather than with the conventional bands containing spun-up larvae. It was noticed that the females had some difficulty in locating the hosts when these were not actually in the surface grooves of the corrugated paper with the cocoon fully exposed to the actions of the parasite. This point is of practical interest since it was noticed in field examination of the burlap bands that the larvae parasitized by

this species were frequently those near the edges of the bands. It is quite possible that the majority of the host larvae in the bands and under the bark are inaccessible to the females.

At 75° F. oviposition continued daily until 3 or 4 days before death, which occurred on the average 30 days after emergence from the cocoons. No exact counts of the numbers of eggs deposited by individual females were made, and females were simply noted as laying up to 10 eggs during the first week of life, and later 3 or 4 per day. It is estimated that a female probably parasitized at least 80 hosts during life, and there was an appreciable amount of superparasitism. On rare occasions two specimens developed on one host.

The egg hatches within 48 hours at 75° F., the larvae immediately starting external feeding. Within another 6 or 7 days four larval moults take place, the cocoon is spun within the codling moth cocoon, and the larval meconium is cast. The pupal stage lasts 10 days so that the entire cycle takes about 18 days at this temperature. Males have been obtained within as short a time as 13 days; this sex usually appears a few days before the female.

McClure (20) has published some notes on two types of life cycles with the male of this species. A small larval type only partially devoured the hosts, went through a relatively brief resting period of 1 to 7 days, and then transformed; a large larval type, which completely devoured the host except for the head capsule and a piece of dried skin, went into a prolonged resting stage of from 37 to 63 days. Reared under controlled conditions, 13% of the progeny had long cycles, 47% short cycles, and 40% died. This variation has not been observed during the maintenance of small laboratory stocks of this species in California in the winter and spring months of 1941–42. The same author states that the breaking open of the codling moth cocoon and exposure of the parasite cocoon to light, results in the latter's colour changing from white, through yellow, to black. Parasites bred at the Riverside insectaries have all spun cocoons which remained white even when freely exposed to air and light in small open vials. Cocoons of white, brown, etc., hues are, however, common in the field (Flanders, 15).

(ii) *Aenoplex betulaecola* Ashm.

This species has recently been recognized by Cushman (135) as synonymous with *A. plesiotypus* Cush., also recorded from Codling Moth (Cushman, 8). The few specimens obtained in the present survey were solitary, and it may be assumed that the general biology is similar to that of *A. carpocapsae.*

(iii) *Lixophaga orbitalis* Aldr.

A few details of the seasonal history of this species are available. First brood summer larvae are parasitized by the *Lixophaga* females which emerge from the overwintering codling moth larvae. An unknown number of generations may intervene between this time and late September, when the Tachinid is found as a first or second instar larva inside the hibernating host larva. This species remains in this stage until the following April and May,

when development is resumed. The mature maggot soon emerges from the *Cydia* caterpillar, and the puparium is formed inside the cocoon of the host. Emergence of the adults occurs in about 15 days' time. Appreciable mortality in the puparia within the host cocoons was recorded in the overwintering material of 1941–42.

Attempts to rear this species in the laboratory were not successful because of failure to secure mating. No obvious reason can be advanced for this lack of interest by the males. The sexes, usually with a preponderance of males, were confined in vials and cages of various sizes (cages from 4″ by 5″ by 9″ to 3′ by 3′ by 3′) supplied with food, water and wormy apples and kept in several temperature and light conditions at different hours of the day. At intervals, some of the females were dissected but no eggs had descended into the uterus though the extensive tracheation and structure of this organ indicated that prolonged incubation of the eggs is needed.

Townsend (28) claims that *L. orbitalis* Aldr. and two other species should be placed under the genus *Prolixophaga* pending the erection of a new genus for the three species, and states (27) that *Prolixophaga* parasitizes codling moth, peach moth and similar boring caterpillars, the females larvipositing at the entrance to the burrows. A similar reproductive habit is recorded for *Lixophaga* and *Euzenilliopsis*, and in this latter genus Townsend has apparently included the common larvipositing Tachinid of the sugar cane borer (*Lixophaga diatraeae* Tns., (Scaramuzza, 22) ). Californian records of *L. variabilis* Coq. are put under *L. orbitalis* by Aldrich (1), but Townsend (27) maintains that rearing records of *Lixophaga* by both Coquillet and Aldrich have been greatly confused, and that those under *variabilis* bred from *Carpocapsa* were quite certainly *Prolixophaga*. Dr. Reinhard of Texas informs the writer that the species *L. orbitalis* Aldr. is known only from California.

Ignoring this systematic confusion, and judging by the reproductive system and large membranous type of egg of the Californian species, it is probable that the female deposits larvae, or larvae in choria, on the surface of the fruit.

(iv) *Ischnus* n.sp.

Three females reared from codling moth pupae in the summer of 1941 were supplied with larvae, prepupae, and pupae in cocoons. All females took an active interest in the hosts, extensively stabbing some of the pupae. However, only one female deposited eggs. These were placed externally on pupae, but although some of these were transferred to coddled larvae and treated in the same way as in the rearing of *Aenoplex* larvae, all specimens died. Eggs left on the pupae hatched normally but the larvae were unable to survive beyond the first instar, being apparently unable to obtain sufficient nourishment on the strongly chitinized hosts. The external oviposition on pupae is rather puzzling since when collected in the field the cocoons of the parasites were spun within the burst skins of the codling moth pupae. This suggests that the species is either an internal parasite or an external parasite which effects entry into the host at some period of its larval life. Nothing is known of its seasonal history.

(v) *Other Species*

Of the remaining parasite species collected, the only information obtained is that of their status. The Tachinid *Anachaetopsis tortricis* Coq. attacked the larvae, the Ichneumonid *Ephialtes sanguiniepes* Cress. was an internal parasite of spun-up larvae, the Braconid *Macrocentrus ancylivorus* Rohw. parasitized the early larval instars in the host fruit, and the Chalcid *Dibrachys cavus* was a gregarious external on spun-up larvae in the summer brood.

## SOME PREVIOUS RECORDS OF CODLING MOTH PARASITES AND PREDATORS IN EASTERN AND WESTERN STATES

For purposes of comparison it is thought useful to include the results of the more detailed investigations on the natural control of the codling moth in North America within the last thirty years.

In 1911–13 Brooks and Blakeslee (7) studied the codling moth in the Central Appalachian region. The work was done by banding 10 to 15 medium sized unsprayed apple trees in ten localities in Virginia, West Virginia, and Maryland, and during the investigation approximately 20,000 larvae were taken from the bands. The authors made no general statement on the importance of natural enemies, and simply recorded that the total parasitism (larval) for all points in 1912 was 0.36% and in 1913, 1.55%. Six Hymenopterous parasites were listed, namely, *Ascogaster quadridentatus* Wesm., *Itoplectis marginatus* Prov., *Macrocentrus* sp., *Meteorus* sp., *Microdus* (*Bassus*) n.sp. and *Phanerotoma tibialis* Hald. The *Ascogaster* outnumbered all other species. A few specimens of (*Hypostena*) *Tachinophyto variabilis* Coq. were also obtained from the larvae. Among the more important predators noted were the ants, *Solenopsis molesta* Say, and *Lasius niger* L. var. *americana* Emery, and the larvae and adults of the beetle *Tenebroides corticalis* Melsh.

More recent studies in Northern Georgia are those of Webb (30) who claimed that "a combination of several native larval parasites form a very important factor in controlling codling moth in N. Georgia." while Webb and Alden (31) stated that 2,593 emergences from 1st, 2nd and 3rd brood larvae during the period 1936–39, 19.1% were parasites. *Ascogaster quadridentatus* and the secondary *Perilampus* sp. constituted 95% of the total parasite figure, with *Pristomerus agilis* Cresson, *Phanerotoma tibialis* Hald. and *Calliephialtes grapholithae* Cress. all considered "of minor importance." By a somewhat unusual arithmetical process, and presumably allowing for the mass field liberations of *Trichogramma minutum*, these authors concluded that the parasites of "the egg and larvae of the codling moth destroy 64.6% of its population." This somewhat high opinion of the controlling effect of parasites in Georgia is endorsed by Webster (32).

Annand (2) reported that work over several years on a mechanical-biological control program for codling moth in West Virginia did not permit of accurate determination of the value of the various natural control factors, though parasite populations remained consistently low while the predators, particularly ants, were more numerous in the untreated orchards.

This author concluded that under certain conditions such a control program gives the grower returns comparable to those obtained with routine spray applications. Unfortunately, no detailed figures of the parasitism of the host during this experiment are available in the published report, but it may reasonably be inferred that the position showed no very significant difference from that noted by Brooks and Blakeslee above.

Boyce (6) observed a variety of parasites and predators in the Niagara district of Ontario in 1937–40, but these were not sufficient for economic control of the host in the sprayed and unsprayed orchards investigated.

In the West a fairly extensive examination of the codling moth problem was made in the Grand Valley of Colorado in 1915–16 by Siegler and Plank (23). *Tenebroides corticalis* Melsh. and a spider *Coriarachne versicolor* Keys were recorded as predators, and *Trichogramma minutum* Riley, *Dibrachys clisiocampae* Fitch, and *Arthrolytus apatelae* Ashm. as parasites. The workers considered that these enemies played a very unimportant part in checking the moth in the area under investigation.

In New Mexico orchards, Garcia (17) reported that the only parasite obtained from bands was *Dibrachys boucheanus* Ratz., and that the coleopterous predator *Cymatodera aethiops* Wolcott continued to be the most evident enemy. Doten (10) investigated the Hymenopterous parasites of *C. pomonella* in Nevada from 1910 to 1915 and recorded *Aenoplex* sp. nov., *Pimpla* sp. nov., and *Meraporus* sp. nov., the latter a gregarious internal Chalcid in the host pupae. No indication was given of the extent of the attack by these species, but in 1915, the author stated that there was little indication that they would ever be of any great importance in checking the codling moth. *Secodella acrobasidis* Craw. was observed as an external parasite of *C. pomonella* larvae within the host fruit at Mesa, Idaho, by Wakeland (29) but although the host infestations were noticeably mild in that district, Wakeland saw no reason to believe that the parasite was of primary importance in that connection. Yothers, Allen and Scheffer (33) found a high percentage of parasitism (in July and August, 80–84%) of codling moth eggs by *Trichogramma minutum* in Wenatchee, Washington. Parasitism was noted throughout north central Washington, and as a rule higher in unsprayed or poorly cared for orchards, while little or no parasitism was noted in well-cared for orchards.

In California, no extensive study of the natural enemies of codling moth in apples appears to have been made. Hensill (18) obtained the parasites *Lixophaga variabilis* Coq. and *Ascogaster quadridentatus* from several thousand larvae collected from bands in the Santa Clara Valley. Parasitism by the former was up to 5% in some lots, but only a few specimens of the latter were taken.

With walnuts, Quayle (21) mentioned *Trichogramma minutum*, *Aenoplex carpocapsae*, and Carabid and Clerid beetle larvae, but he considered that seldom, if ever, were the enemies of codling moth important enough in themselves to exercise satisfactory control. Likewise, Boyce (5) in a later paper on codling moth in Persian walnuts, generalized to the effect that "natural enemies do not ordinarily exert a sufficient effect upon the codling moth population in walnuts to warrant consideration in the control programme."

Flanders (15) summarized the findings of four years' observations on Cydia parasites and predators in the vicinity of Saticoy, Ventura County. The following species are given: *Aenoplex carpocapsae* Cushm., *A. plesiotypus* Cushm., *Aenoplex* n.sp., *Ephialtes sanguiniepes* Cress., *Exetastes* n.sp, *Trichogramma* sp., *Prospaltella* sp., and *Lixophaga* n. sp., as parasites and *Cymatodera angustata* Spin., *C. ovipennis* Lec., and *Hydnocera scabra* Lec. as predators. The most prominent checks were the *Aenoplex* spp., and *Trichogramma* spp. It was estimated by this author that 50% of the host eggs deposited in May and June were parasitized by the latter, while regarding *Aenoplex*, it is recorded that: "At Carpinteria 20% of 800 larvae found in bands on the walnut trees were parasitized. On Oct. 24, 1925, the band on a large crabapple tree at Saticoy contained 32 larvae; of these 22 were parasitized." However, in an earlier paper in 1926, Flanders (14) adds that in the neighbourhood of this latter tree, 32 of the 417 *Cydia* larvae collected were parasitized, so that the parasitism of the one tree was exceptional. Other figures for parasitism were published in 1926, when 24 specimens of *Lixophaga* emerged from 300 overwintering larvae, and in 1929, (16) where it is stated that on Sept. 1, 1928, a random sample of 50 immature larvae from a walnut orchard where *Calliephialtes* n. sp. has been observed, gave 15 parasitized, that is a 30% parasitism. Some notes on this latter larval parasite—*Calliephialtes nucicola* Cushm.— are given by Barrett (3), who claimed that it was quite common in some walnut orchards of Ventura County in the summer of 1929, and 141 specimens were reared between Aug. 17 and Sept. 20th from infested walnuts. (In the summer of 1941, Mr. Barrett informed the writer that this emergence was from 5 to 6 tons of blighty, wormy nuts so that the descriptions of the parasite's incidence as "quite common" is misleading.)

The foregoing review of the more important published data on codling moth parasites and predators in N. America indicates that most workers regard these enemies as of little controlling value. In certain sections investigations of rather limited nature have suggested that they play a significant rôle, and even in these cases the effective work is attributed mainly to the egg parasite *Trichogramma* spp., and the (probably introduced) *Ascogaster quadridentatus*. The larvae and pupae of the pest have attracted strikingly few native parasites, and those species which have attacked this host never appear to build up high populations.

## DISCUSSION

The results of the foregoing survey for native parasites and predators of the codling moth larvae and pupae in California reveal that the position there is little better than that found by similar investigations in other sections of N. America. Some of the orchards examined have been untreated for as long as 15 years, yet the populations of the few native natural enemies seem to have remained very low while the resident codling moth population has remained relatively high and caused considerable annual crop losses to the growers. Though of sporadic distribution, the introduced species *Ascogaster quadridentatus* is probably the most effective larval parasite in the state. The native Tachinid *Lixophaga orbitalis* did not build up appreciable populations in the course of the 1941 season though it was present early in the year in most areas investigated; there

is good reason to believe that the species is already exerting its maximum effect on the host. The ectoparasitic species of *Aenoplex* on the spun up larvae are not well adapted to exercise appreciable control on the host because of the intervention of a diapause in their life histories at a time when the codling moth is rapidly building up, and moreover, doing all the economic damage. Further, the Ichneumonid's very low incidence in the summer broods of the codling moth suggests that other hosts may be utilized in this period.

The rather sharp contrast between some of the data obtained in the present work and those of Flanders (13 to 16) is possibly due to two factors. Firstly, the intensification of insecticide treatments since that time may have greatly reduced the native parasite populations, and, secondly, the samples taken by Flanders may have been too small for a true representation of the part played by parasites. A reasonable statement of the position in regard to the role of natural enemies of codling moth in California is that of Quayle (21) and Boyce (5) that they are not of sufficient effect to warrant much consideration in the control program.

It has been remarked above that in this lack of any effective controlling action by native parasites and predators, the position in California appears similar to that in other parts of N. America. There are some data to show that, under favourable conditions, egg parasitism by *Trichogramma* spp. becomes high late in the season in a few areas in America, but for satisfactory control these parasites should destroy a high proportion of the eggs when the host populations are low, and this they are apparently unable to do. The action of the native larval and pupal parasites and predators, however, is even more unsatisfactory since there is no evidence that they destroy a high proportion of the host even when the latter is abundant. On the basis of published data and the present survey in California, it might almost be claimed that these species are little more than "casual" enemies of the codling moth. In view of the long period during which the moth has been recognized as a pest in N. America, the behaviour of the native enemies is discouraging and there is no reason to expect any improvement.

The question of the desirability of introducing any of the Californian species into Canada requires only brief notice in view of the ineffective nature of these forms. *Aenoplex carpocapsae* is known to occur in the central Appalachian range, Illinois, etc., and as there are no obvious geographical barriers to its spread into Canada, its absence (or extreme rarity) there is probably due to some other natural factors. In California this species is not more abundant than in some of the eastern states, and it is very doubtful if any useful purpose would be served by liberating colonies in Eastern Canada. The Tachinid *Lixophaga orbitalis* is said by Reinhard to be known only from California but it has already been noted that considerable taxonomic confusion obtains regarding the identity of the *Lixophaga* species which have been reared from codling moth in eastern and western states. It is therefore possible that the species already exists in the East, though apparently with a lower incidence than in California, and its liberation in Canada might thus be worth a trial. The Clerid and Raphidid predators were not recovered in Boyce's survey in the Niagara district, and these also deserve consideration for introduction.

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# NOTES ON THE LONGEVITY, SPORULATION AND DIAGNOSIS OF *BACILLUS LARVAE*, THE CAUSE OF AMERICAN FOULBROOD OF BEES[1]

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In the diagnosis of American foulbrood of bees it is important to supplement microscopic examination of suspected samples with cultural tests to establish the identity of the causal organism, *Bacillus larvae*. Cultural tests are imperative in determining the presence of viable spores in comb which has been subjected to treatment by heat or chemicals. For successful cultivation *in vitro* of *B. larvae* special media are required, the organism failing to grow on ordinary laboratory substrates. The earlier media employed contained such substances as crushed brood or egg yolk. In this laboratory more easily prepared media containing peptone, yeast extract and carrot or turnip extract have been found useful in the routine diagnosis of American foulbrood (2, 3, 4). In a more recent study of the growth requirements of *B. larvae* (5) a simple medium containing peptone and thiamin was found to permit good growth of the organism.

The viability of *B. larvae* on artificial media has been consistently noted to be poor. The majority of the vegetative cells die and undergo autolysis so that transfers made after 2 weeks or more are frequently sterile. This poor viability is doubtless related to the difficulty in inducing spore formation *in vitro*, in spite of the fact that in samples of foulbrood scale as ordinarily found, the organism consists entirely of spores. In the earlier studies of *B. larvae*, White (13) recognized the difficulty in obtaining spores on certain laboratory media, especially those containing sugar. Tarr (9) reported improved spore production by inclusion of a phosphate buffer in a medium to neutralize acid formation from sugar. Holst and Sturtevant (1) proposed a medium for stock cultures as well as for the production of spores. Though permitting abundant growth of the organism this medium (which contains 1% glucose) has not given good results in our hands from the standpoint of maintaining viability or that of spore production. The experiments here reported were planned to study further certain factors affecting longevity and sporulation of *B. larvae* and also its cultivation from foulbrood scale.

## EXPERIMENTAL

### *Longevity of Bacillus Larvae*

The viability of *Bacillus larvae* was studied using two media, peptone yeast carrot extract agar (3), and peptone thiamin agar (5), each prepared with and without the addition of 1% glucose. Six strains of the organism,

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freshly isolated from scale, were inoculated in triplicate to slants of each medium. After incubation at 37° C. for 4 days, the tubes were plugged with cork stoppers and stored at room temperature. A similarly prepared series was stored at 4° C. Periodic transfers were made by 1 mm. loop inoculation to tubes of yeast carrot semi-solid agar, and cultures observed for growth and nitrite formation after incubation at 37° C. for 2 weeks.

TABLE 1.—LONGEVITY OF *Bacillus larvae* ON AGAR MEDIA*

| Storage (days) | Peptone yeast carrot extract agar | | Peptone thiamin agar | |
|---|---|---|---|---|
| | + glucose | − glucose | + glucose | − glucose |
| | storage at room temperature | | | |
| 10 | 17 | 18 | 15 | 18 |
| 20 | 8 | 18 | 4 | 18 |
| 30 | 8 | 18 | 8 | 18 |
| 50 | 5 | 13 | 5 | 14 |
| | storage at 4° C. | | | |
| 10 | 14 | 18 | 15 | 18 |
| 20 | 6 | 11 | 2 | 8 |
| 30 | 5 | 14 | 3 | 14 |
| 50 | 4 | 8 | 0 | 7 |
| 75† | 8 | 18 | 9 | 17 |

* Figures indicate number of tubes showing growth on transfer to yeast carrot semi-solid agar (18 cultures tested, 6 strains in triplicate).

† Very heavy inoculum.

Results of this test, summarized in Table 1, indicate the unfavourable effect of glucose on the viability of *B. larvae* on both media and at both temperatures. With all modification of the media decreased viability was noted within 50 days. Storage at room temperature was rather more favourable to longevity than that at 4° C. With a particularly heavy inoculation, made after 75 days, it was possible to demonstrate the presence of viable cells in a greater number of cases. However, the unfavourable effect of glucose was still evident.

Further evidence of the effect of glucose is noted in Table 2, giving results from a similarly conducted test of 13 strains of *B. larvae* grown on the "stock culture" medium of Holst and Sturtevant (1) and on a similar medium without glucose. Six of the strains failed to grow when transferred after 45 days' storage at 4° C. on the stock medium (containing glucose), though all remained viable after 120 days in the absence of glucose.

TABLE 2.—EFFECT OF GLUCOSE ON LONGEVITY OF STRAINS OF *B. larvae* ON PEPTONE YEAST EXTRACT AGAR*

| Strain | 45 days at 4° C. | | | | 120 days at 4° C. | | | |
|---|---|---|---|---|---|---|---|---|
| | + glucose | | − glucose | | + glucose | | − glucose | |
| | Growth | $NO_2$ | Growth | $NO_2$ | Growth | $NO_2$ | Growth | $NO_2$ |
| A | 4 | + | 4 | + | 4 | + | 4 | + |
| B | 3 | + | 3 | + | 4 | + | 4 | + |
| C | 4 | + | 4 | + | 4 | + | 4 | + |
| D | 4 | + | 4 | + | 4 | + | 4 | + |
| 10 | 4 | + | 4 | + | 4 | + | 4 | + |
| 20 | 0 | − | 3 | + | 0 | − | 4 | + |
| 21 | 0 | − | 4 | + | 0 | − | 4 | + |
| U | 0 | − | 3 | + | 0 | − | 4 | + |
| V | 0 | − | 4 | + | 0 | − | 4 | + |
| W | 4 | + | 4 | + | 4 | + | 4 | + |
| X | 0 | − | 3 | + | 0 | − | 4 | + |
| Y | 4 | + | 4 | + | 4 | + | 4 | + |
| Z | 0 | − | 2 | + | 0 | − | 4 | + |

* 0, 1, 2, 3, 4 = degrees of growth on transfer to yeast carrot semi-solid.

To study the longevity of *B. larvae* in soil, 2.5 ml. amounts of cell suspensions in water from 72-hour slant cultures on "stock" medium were added to 10 gm. of finely ground, sterile soil in 125-ml. Erlenmeyer flasks, plugged with cotton to permit desiccation and kept at room temperature. Six strains were tested in duplicate. Viability tests were made at intervals by transferring two 3-mm. loopfuls to yeast carrot semi-solid. The data in Table 3 indicate a decrease in viability with all strains after 50 days. However, use of a heavy inoculum (10 loopfuls) showed the presence of viable cells after 228 days.

TABLE 3.—LONGEVITY OF 6 STRAINS OF *Bacillus larvae* IN DRY SOIL*

| Storage (days) | Strain of *B. larvae* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | | B | | X | | 10 | | 20 | | 21 | |
| | Growth | $NO_2$ | Growth | $NO_2$ | Growth | $NO_2$ | Growth | $NO_2$ | Growth | $NO_2$ | Growth | $NO_2$ |
| 20 | 4 | + | 4 | + | 4 | + | 4 | + | 4 | + | 4 | + |
| 30 | 4 | + | 3 | + | 4 | + | 3 | + | 4 | + | 4 | + |
| 50 | 2 | + | 0 | − | 2 | + | 0 | − | 0 | − | 0 | − |
| 75† | 4 | + | 4 | + | 4 | + | 4 | + | 4 | + | 4 | + |
| 158† | 4 | + | 4 | + | 4 | + | 4 | + | 4 | + | 4 | + |
| 228† | 4 | + | 4 | + | 4 | + | 4 | + | 4 | + | 4 | + |

* 0, 1, 2, 3, 4, = degrees of growth on transfer to yeast carrot semi-solid.
. Very heavy inoculum.

*Spore Production*

In the preceding tests microscopic examination of the cultures showed that spore formation was almost entirely suppressed in all cases where glucose was added. Without added glucose, spore formation was generally abundant with indications of considerable strain variation. Of the media

tested, "stock" medium of Holst and Sturtevant, prepared without glucose, was the most reliable for spore production. In Table 4 are presented results from a test with 13 strains of *B. larvae* grown on "stock" medium, with and without glucose, including a duplicate series in which culture tubes were stoppered immediately after inoculation. Whereas spore formation was inhibited in the presence of glucose, it was evident in all cultures when sugar was absent, being specially abundant in the sealed tubes. This test was repeated with 12 fresh isolates of *B. larvae* and similar results obtained.

TABLE 4.—SPORULATION OF *Bacillus larvae* ON PEPTONE YEAST EXTRACT AGAR AS AFFECTED BY GLUCOSE AND SEALING OF CULTURE TUBES*

| Strain | Glucose added | | | | No glucose | | | |
|---|---|---|---|---|---|---|---|---|
| | Sealed | | Unsealed | | Sealed | | Unsealed | |
| | 6 days | 12 days | 6 days | 12 days | 6 days | 12 days | 6 days | 12 days |
| A | 0 | 0 | 0 | 0 | 4 | 4 | 2 | 3 |
| B | 0 | 0 | 0 | 0 | 4 | 4 | 2 | 3 |
| C | 0 | 0 | 0 | 0 | 4 | 4 | 3 | 4 |
| D | 0 | 0 | 0 | 0 | 4 | 4 | 4 | 3 |
| 10 | 0 | 0 | 0 | 0 | 4 | 4 | 4 | 4 |
| 20 | 0 | 0 | 0 | 0 | 2 | 3 | 1 | 2 |
| 21 | 0 | 0 | 0 | 0 | 4 | 3 | 2 | 2 |
| U | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 1 |
| V | 0 | 0 | 0 | 0 | 4 | 4 | 2 | 3 |
| W | 0 | 0 | 0 | 0 | 4 | 4 | 2 | 3 |
| X | 0 | 0 | 0 | 0 | 4 | 4 | 2 | 3 |
| Y | 0 | 0 | 0 | 0 | 4 | 3 | 3 | 2 |
| Z | 0 | 0 | 0 | 0 | 4 | 4 | 1 | 3 |

* 0,1, 2, 3, 4, = degrees of sporulation.

In an attempt to explain the favourable effect of sealing, 48-hour cultures on "stock" agar without glucose were transferred to an atmosphere of $CO_2$ and also to one in which oxygen was removed by suction and pyrogallic-potash. Further growth and sporulation were suppressed in both cases, while in the latter environment most vegetative cells rapidly disintegrated leaving the pre-formed spores in the free state.

*Comparison of Diagnostic Media*

For the purpose of diagnosis of American foulbrood in suspected samples of comb a medium giving prompt development from small inocula of spores is desirable. The chief media employed for this purpose have contained crushed brood (6, 11), egg yolk (12), egg yolk and yeast (7), yeast and carrot or turnip extract (2, 3, 4) chicken embryo (10), and yeast carrot extract and cysteine (1). Some of these substrates such as those made from brood, egg, or embryo, are more difficult to prepare and have the disadvantages of being opaque and not suited to pressure sterilization, making them less satisfactory for routine use.

A comparison was made of the more simply prepared media, to study the effect of including various ingredients on the ability of the substrate to permit growth of inocula containing different numbers of spores from

foulbrood scale. To a basal inorganic solution (5), peptone 1%, glucose 1%, yeast extract 0.5% and carrot extract, 200 ml. per litre (3) were used in the combinations indicated in Table 5 to prepare semi-solid (0.3% agar) media. From a suspension of crushed scale, standardized by direct microscopic count, dilutions were prepared containing from 40 to 4,000,000 spores of *B. larvae* per ml. One ml. of each dilution was used as inoculum.

TABLE 5.—COMPARISON OF SEMI-SOLID MEDIA FOR DETECTION OF *Bacillus larvae* IN SUSPENSIONS OF CRUSHED SCALE

| Medium | Number of spores in scale suspension (per ml.) | | | | | |
|---|---|---|---|---|---|---|
| | $4 \times 10^6$ | $4 \times 10^5$ | $4 \times 10^4$ | $4 \times 10^3$ | $4 \times 10^2$ | $4 \times 10^1$ |
| Peptone | 0 | 0 | 0 | 0 | 0 | 0 |
| Peptone, glucose | 3 | 2 | 1 | 0 | 0 | 0 |
| Peptone, yeast | 3 | 3 | 3 | 2 | 3 | 1 |
| Peptone, yeast, glucose | 3 | 3 | 3 | 3 | 3 | 3 |
| Peptone, carrot | 2 | 0 | 0 | 0 | 0 | 0 |
| Peptone, carrot, glucose | 3 | 1 | 2 | 0 | 0 | 0 |
| Peptone, yeast, carrot | 3 | 3 | 3 | 3 | 3 | 3 |
| Peptone, yeast, carrot, glucose | 3 | 3 | 3 | 3 | 3 | 3 |

Figures represent number of positive tubes (out of 3).

Development of *Bacillus larvae* after 10 days' incubation at 37° C., as indicated by macroscopic growth and a positive nitrite test, is shown in Table 5. Three of the media, all containing yeast, were positive with all tubes inoculated with the most dilute spore suspension. Glucose, though detrimental to longevity and spore production, exerted a favourable effect in the absence of yeast in media designed for diagnostic purposes.

TABLE 6.—EFFECT OF MEDIUM AND TIME OF INCUBATION ON DEVELOPMENT OF SPORES OF *Bacillus larvae* FROM DILUTE SUSPENSIONS OF CRUSHED SCALES

| Spore count per ml. | Medium | No. of tubes | Number of tubes positive | | |
|---|---|---|---|---|---|
| | | | 5 days | 10 days | 15 days |
| 3.6 | Peptone yeast glucose semi-solid | 10 | 8 | 9 | |
| | Peptone yeast carrot semi-solid | 10 | 9 | 9 | |
| | Peptone yeast carrot glucose semi-solid | 10 | 8 | 8 | |
| | "Diagnostic medium" (solid)* | 10 | 5 | 8 | |
| 3.6 | Peptone yeast carrot semi-solid | 50 | 15 | 38 | 46 |
| | "Diagnostic medium" (solid) | 50 | 9 | 44 | 47 |
| 4.1 | Peptone yeast carrot semi-solid | 50 | 20 | 22 | 22 |
| | "Diagnostic medium" (solid) | 50 | 4 | 13 | 15 |

* Holst and Sturtevant.

Further tests on the ability of different media to initiate growth of *B. larvae* from dilute spore suspensions from scale are summarized in Table 6. The data show results from tests with three different scale suspensions. One ml. of inoculum was used, added to the semi-solid medium

and incorporated by shaking, and, in the case of the solid agar, to slants which were then incubated upright. While the percentage of positive tubes varied with the scale suspension, and is probably related to the number of "non-viable" spores present, the semi-solid media gave in all cases a noticeably greater proportion of positive tubes after the shortest incubation period. With more prolonged incubation such differences tended to disappear. The data support the findings of Sturtevant (8) who showed that seedings of smaller numbers of spores frequently require a prolonged incubation before vegetative growth is produced.

Using a slanted solid medium containing yeast, carrot and egg yolk, to which 1 ml. of inoculum was added, Sturtevant (8) found that a minimum of 50,000 spores was required to produce vegetative growth. Later Holst and Sturtevant (1) state, without presenting data, that with their "diagnostic medium" the lag phase preceding germination is greatly reduced, as compared with egg-yolk medium, and that with the former growth may occur "with an inoculum of one or only a few spores". Tarr (10) using a chicken embryo medium, obtained growth with inocula containing 1,000, and in some cases as few as 100 spores.

Since our medium and the "diagnostic medium" of Holst and Sturtevant both contain peptone, yeast, and carrot extract it is felt that the advantage of the former in initiating more rapid germination of small numbers of spores is largely due to its being semi-solid. It has been consistently our experience that development in semi-solid begins slightly below the surface, suggesting that here more suitable conditions for germination obtain than in the liquid-solid system of the slanted agar cultures. The inclusion of inorganic salts may also be of value in the semi-solid media.

## SUMMARY

The incorporation of glucose in media for the cultivation of *Bacillus larvae* noticeably decreased the longevity of the organism. In dry soil it was found viable when tested after 228 days.

Sporulation was almost completely suppressed in the presence of glucose. Media without added sugar were suited to spore formation which was noticeably favoured by sealing the culture tubes.

A semi-solid medium containing peptone, yeast, and carrot extract permitted more rapid germination from inocula of small numbers of spores (less than 5) than a solid medium containing these ingredients. Consequently this semi-solid medium is recommended for the diagnosis of *B. larvae* in comb suspected of containing American foulbrood.

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# DETERMINATION OF FLESHING CHARACTERISTICS IN MARKET POULTRY[1]

## II. TURKEYS

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Two of the most striking features of dressed turkeys are their abruptly prominent keel and their characteristically slabsided appearance. In recent years the Broad Breasted and the Beltsville Small White breeds have added a new feature to the turkey population of this continent in so far as in both cases the breasts of the dressed carcasses present a decidedly more rounded and fleshy appearance than is the case with the more familiar breeds. This difference is so marked and potentially of such economic importance that an inquiry into its nature was undertaken. The immediate concern of this investigation was to determine whether slabsidedness in turkeys is caused by the inordinately prominent keel or is of muscular origin, and whether the factors involved are amenable to selection.

Apparently Jull (7) was one of the first to draw up a definitely formulated program for improvement of fleshing characteristics of turkeys. He stated his objective as being "a relatively short-legged, long-bodied, early-maturing, good-fleshing type of white feathered turkey". Through a market survey Smith (10) determined at this time (1935) that the popular demand was for a medium sized turkey from 11 to 14 pounds. The Beltsville Small White variety was apparently the outcome of these various considerations. Later Jaap (4) and Jaap and Penquite (5) studied the conformation of body shape by expressing linear body measurements as ratios of the cube root of body weight. By virtue of such ratios a differential shape response of individual breeds to different degrees of fleshing was found in rib spread, anterior depth and shank length. Jaap, Thompson and Milby (6) found that by selecting parents for proportionately short shanks, long keels and shallow bodies, progeny was obtained which excelled in body weight. However, in view of the questionable nature of Jaaps ratios, which has been discussed by Lerner (8, 9) and mentioned by Bird (3) the significant observation seems to be that, throughout all the breeds that were studied, the birds which were adjudged to show a superior degree of fleshing were at the same time those that reached the greatest average body weight for each breed. Asmundson and Lerner (1) found that the weight of the pectoralis major was more dependent on the length of the underlying sternum than on length of leg. Bird (3) showed that the entire musculature dissected off the pectoral region and the posterior extremities of White Leghorn and Barred Plymouth Rock roasters was closely correlated to the deviation of observed from expected body weight relative to length of tibia. Such deviations, which were termed "fleshing indices", were however found to be unreliable estimates of roundness of breast since this characteristic depended fully as much on the depth through the

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thoracic girdle as upon absolute volume of fleshing. Thus an excessively deep bodied bird might present a quite slabsided appearance in spite of a high fleshing index, while a shallow carcass could be fairly deficient in fleshing and still be very attractively round in the breast. Since fleshing indices and thoracic depth both showed familial segregation in Barred Plymouth Rocks it was hoped that application of this technique to several breeds of turkeys might yield similarly reliable determinants of their fleshing and appearance and thus facilitate progeny testing for these characteristics in turkeys.

## MATERIAL AND METHODS

Eighty birds were used in this study, including 20 males of each of three breeds, Standard Bronze, Broad Breasted and Beltsville Small White, and 5 Bourbon Red males and 15 Standard Bronze females. All birds were of the same age and raised under comparable conditions in adjoining runs and on identical feed which, in the starter ration contained 25% protein and 22% in the growing ration. It was intended to kill the birds at 27 weeks of age but on account of heavy snow storms this had to be postponed till the 29th week. The procedure when collecting the data was as outlined previously for chickens (3). The birds were measured, and after starving over night they were weighed, killed, dressed, graded and placed in cold storage. On removal from storage, tracings were made of cross-sections which were cut just forward of the anterior point of the keel; the entire musculature was then dissected off the pectoral region and the posterior extremities and weighed. No attempt was made to secure the weight of the skeleton and consequently no determination of total edible portion was made. As a ready reference a tracing from each breed is reproduced in Figure I. The tracings depict in each case a bird that, for each breed, yielded the mean weight of muscle and was possessed of approximately the mean depth of torso. Thus the shape and degree of fleshing of each tracing are typical of each breed as represented by the available samples.

## FLESHING OF BREAST

From the individual sections of each breed the measurements along the median line from A to B and from B to C, as shown in Figure I No. 5, were obtained. These data are presented in Table 1.

Table 1.—Mean depths through the thoracic girdle

| | | Depths | | | $\frac{AB \times 100}{BC}$ |
|---|---|---|---|---|---|
| | | AC | BC | AB | |
| | | mm. | mm. | mm. | |
| 20 Bronze | Males | 233.9 | 143.5 | 90.4 | 63.12 |
| 20 Broad Breasted | Males | 233.4 | 139.1 | 94.3 | 68.04 |
| 5 Bourbon Red | Males | 212.5 | 131.4 | 81.1 | 62.34 |
| 20 Small White | Males | 202.6 | 119.4 | 83.2 | 69.75 |
| 15 Bronze | Females | 185.5 | 111.2 | 74.3 | 66.92 |
| 50 Barred P. Roc, | Males | 131.2 | 85.8 | 45.4 | 52.91 |

FIGURE I. Cross sections cut just forward of the anterior point of the keel. 1. Broad Breasted male. 2. Standard Bronze male. 3. Small White male. 4. Bourbon Red male. 5. Standard Bronze female. 6. White Leghorn male. 7. B.P. Rock male. 8. Dark Cornish male. 9. Ringneck Pheasant male. Reduced to 29.2% of natural diameter.

The tracings show that at this section through the torso the pectoralis major extends over the side of the bird to the level of the vertebral hemal spine and that it is thickest and aids in creating the maximum width of the bird at the level at which the pectoral skeleton articulates with the ribs.

Males of the Bronze and Broad Breasted breeds are markedly different in roundness of breast contour but are of equal body depth from A to C. However the former breed has a deeper cavity and hence a lower keel than found in the Broad Breasted as shown by the ratio of AB to BC. An analysis of the individual percentages, after their transposition to degrees of an angle, revealed that in this respect the five breeds segregated into two highly significantly different homogeneous populations. Thus the Small White and Broad Breasted males and the Bronze females, all of which are quite round in breast conformation, are proportionately deeper in keel than the Bronze and Bourbon Red males. The significance of this observation is that the breeds and the sex, as judged by the one available sample, which have the roundest breast are possessed of a pectoral skeleton which potentially will accommodate a proportionately greater volume of muscular tissue than is found on more slabsided breeds.

In an endeavour to estimate the thickness of fleshing over the breast the total width of torso from D to E and width of pectoral skeleton from F to G, as shown in Figure I No. 5, was measured at this level. Hence the combined thickness of the two pectoralis major muscles could be obtained by difference. These data and the relationship of thickness of muscle to width of skeleton are presented in Table 2 and serve as approximate estimates of fleshing over the breast.

TABLE 2.—MEAN WIDTHS THROUGH THORACIC GIRDLE

| | | | Widths | | | $\frac{DF+GE \times 100}{FG}$ |
|---|---|---|---|---|---|---|
| | | | DE | FG | DF + GE | |
| | | | mm. | mm. | mm. | % |
| 16 | *Bronze | Males | 135.2 | 89.4 | 45.8 | 51.33 |
| 17 | *Broad Breasted | Males | 159.0 | 90.8 | 68.2 | 75.11 |
| 5 | Bourbon Red | Males | 132.2 | 77.8 | 54.4 | 69.92 |
| 13 | *Small White | Males | 139.3 | 76.1 | 63.2 | 83.05 |
| 10 | *Bronze | Females | 123.5 | 65.7 | 57.8 | 87.98 |

* Birds the contour of which had been distorted by pressure during storage were excluded from this analysis.

Analysis of these data revealed that Bronze females and Small White males are possessed of superior relative thickness of flesh and do not differ materially from one another in this respect. Broad Breasted and Bourbon Reds form a slightly inferior class while Bronze males are characteristically thin in musculature of the breast. Thus the average apparent fleshing of the breast of these four breeds of turkeys is in fact an approximate measure of their average actual fleshing since muscles tend to become thicker and the breast rounder from one breed to another as the keel that is to be covered becomes deeper. These observations express breed differences. However as will appear later, within breeds the same relationship holds which was found for chickens, namely, that a shallow torso relative to volume of muscle tends to produce a rounded breast.

The Standard Bronze is unquestionably the most important breed on this continent by virtue of its numerical preponderance over all other breeds. It is therefore a misfortune that among turkeys, a species which is raised exclusively for meat purposes, the pectoral skeleton of the principal breed is so shallow that it accommodates a rather small volume of muscle which when stretched over a relatively deep torso results in a carcass which is typically narrow and slabsided.

## FLESHING IN GENERAL

The data which are necessary for an analysis of general fleshing characteristics of the several breeds of turkeys are presented in Table 3. For the sake of comparison, data on three breeds of chickens and on a small sample of Ringneck Pheasants are included.

TABLE 3

| | | Live body weight | Tibia length | Torso depth | Muscles | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Breast | Legs | Br.+Legs | Legs as % of Br. | Legs+Br. as % of remainder |
| | | gm. | mm. | mm. | gm. | gm. | gm. | % | % |
| 20 Bronze Breasted | Males | 11277 | 248.3 | 233.4 | 2224.4 | 1884.0 | 4108.4 | 84.7 | 57.60 |
| 20 Bronze | Males | 9625 | 264.0 | 233.9 | 1770.2 | 1675.1 | 3445.3 | 94.6 | 55.40 |
| 5 Bourbon Red | Males | 8331 | 238.8 | 212.5 | 1480.9 | 1320.6 | 2801.5 | 89.2 | 50.51 |
| 20 Small White | Male | 7916 | 224.3 | 202.6 | 1409.1 | 1204.6 | 2613.7 | 85.5 | 49.34 |
| 15 Bronze | Females | 5971 | 212.3 | 185.4 | 1117.9 | 1024.8 | 2142.7 | 91.7 | 56.12 |
| 50 B.P. Rock | Males | 3082 | 180 | | 386.1 | 620.3 | 1006.4 | 160.7 | 47.03 |
| 55 W. Leghorn | Males | 2137 | 156 | | 254.6 | 378.9 | 633.5 | 148.8 | 42.17 |
| 5 Cornish | Males | 3232 | 161 | | 510.2 | 708.8 | 1219.0 | 138.9 | 60.45 |
| 3 Pheasant | Males | 1201 | 122 | | 294.7 | 256.5 | 551.2 | 87.0 | 70.53 |

It is of interest to note the proportion of weight of leg muscle to that of the breast. In walking birds the breast is relatively poorly developed whereas the opposite is the case for those of a flying habit. Furthermore, these ratios confirm the statement above that Bronze turkeys have the poorest while Broad Breasted and Small Whites have the heaviest development of breast muscle. The mean ratios of the combined weights of breast and leg muscles to weight of the remainder of the starved live weight of birds of the same sex become greater as the breeds show a heavier mean weight of body. This association may mean that internal organs are more stable in weight from one breed to another than is the weight of muscle and it holds between males of all breeds from Broad Breasted turkeys to White Leghorn chickens as shown by a $+0.970$ coefficient of correlation. However, within breeds the correlation is entirely non-existent as measured by the coefficient $-0.085$. This observation in conjunction with the facts that Bronze females show the same relative muscular development as do the males of that breed, that the regressions for turkeys and for chickens, although of similar slope, are not in linear continuation of one another and finally, that Cornish and Pheasants are so radically different from other classes all indicates that the relationship of muscular weight to remainder is governed by definite species and breed differences.

From the data the means of which are presented in Table 3 were obtained the statistical standards which are presented in Table 4.

TABLE 4

| | | log regression $x$ = log body weight $y$ = log tibia length | Correlation coefficients | | | |
|---|---|---|---|---|---|---|
| | | | Log tibia length to log body wt. | Muscle to index | Muscle to remainder | Br.- to leg muscle |
| 20 Broad Breasted | Males | $x = 3.26971 + .32601y$ | .063 | .472 | .486 | .604 |
| 20 Bronze | Males | $x = 2.19054 + .74017y$ | .225 | .271 | .535 | .631 |
| 5 Bourbon Red | Males | $x = 1.39232 + 1.06316y$ | .551 | .676 | .861 | .673 |
| 20 Small White | Males | $x = 1.78781 + .89656y$ | .342 | .938 | .745 | .637 |
| 15 Bronze | Females | $x = 2.46376 + .56364y$ | .229 | .758 | .468 | .757 |
| 50 B.P. Rock | Males | $x = 1.06055 + 1.07904y$ | .340 | .938 | .839 | .867 |
| 55 W. Leghorns | Males | $x = .71778 + 1.84162y$ | .720 | .912 | .906 | .868 |

Assuming that the density of all birds is approximately equal, the proportionate length of leg to volume of torso may be read directly off the regression coefficients. Thus the Broad Breasted turkey has proportionately the shortest legs and is followed in order by Bronze females, Bronze males, Small Whites, Bourbon Reds, B.R. Rocks and White Leghorns, these latter having proportionately the longest legs.

From the regression equations were obtained the expected body weight of each bird relative to its length of tibia, and thus the deviations between these and the observed body weights i.e. the fleshing indices. Table 4 shows that only in the case of the Small White turkeys did the indices predict the actual weight of fleshing of breast and legs with the useful accuracy which was found for chickens. In view of this fact it becomes meaningless to employ either such regressions or simple ratios of anatomical measurements to body weight for the purpose of determining fleshing of any of the turkeys considered, or as bases for estimation of attractive appearance excepting only the Small White breed.

All birds were, as mentioned, alignment graded after dressing. This form of grading is in fact the most accurate estimate obtainable of roundness of breast as shown by the close agreement between rank numbers that were obtained by grading and by independent visual estimate of the tracings of sections. Rank numbers for the Small Whites which expressed the relationship between depth of torso to fleshing indices were found to be in substantial agreement with the results of alignment grading. In the case of other breeds in which the indices did not measure fleshing with appreciable accuracy, and the correlation between weight of breast and leg muscles was low, calculated grading could not be expected to succeed. However, when the actual weight of breast muscles rather than the index for these breeds was expressed as ratios to depth of torso similar satisfactory agreement between calculated and actual roundness of breast was obtained for these as for the Small Whites except in the case of the Standard Bronze males. In this one breed depth of the torso is so highly correlated to weight of breast muscle that slabsidedness becomes fairly uniform. It can therefore be stated as a general rule that within breeds roundness of breast is dependent on depth of torso.

## DISCUSSION

It has been shown that a full development of pectoral musculature of poultry generally is dependent on a deep keel, and hence the low keel of walking birds is accompanied by poorly developed muscles of the breast. Also, that the breeds possessing the greatest relative weight of breast muscles and therefore the deepest keel are those with the most attractively rounded breast. In addition, the heavier a breed is the higher will be the average ratio of muscular tissue to waste. However, within breeds shallowness of torso tends to produce roundness of breast, and likewise within breeds proportion of flesh to waste is independent of the individual body weight although fluctuating within the predetermined breed limits. It therefore appears that the most desirable type of turkey must have maximum depth of keel with a sufficiency of flesh to cover this frame abundantly, thus producing a large and heavy bird. Within this type the shallowest torso will produce the roundest breast and females will tend to be more fleshy and round in breast than the males.

One important requisite for success of the fleshing index technique is a low degree of correlation between tibia length and body weight. In case of a close association here the deviations of observed from expected body weights will be so small that minor experimental errors in dissection or variations in emptying of the alimentary tract during the starvation period may obliterate the correlation of the indices to the actual weight of musculature. Furthermore, even when the correlation remains intact familial segregation may be endangered as was the case with the White Leghorn males (3). For this reason there will be more likelihood of success with birds that have passed the age of active skeletal growth when dispersal from the regression line increases markedly as shown by Asmundson and Lerner (2) and by the log correlation coefficients presented in Table 4, which are in close accord with most of the coefficients for birds after 16 weeks of age as shown by these authors.

The other requisite for success is a practically perfect prediction of muscular weight by the index. Some reasons why turkeys mostly fail in this respect are suggested. The use of tibia length as an index of skeletal size and of body weight as an index of fleshing has several implications. The first of these is the assumption that the weight of muscles of the legs and of the breast are highly correlated. It will be seen in Table 4 that this requirement is satisfactorily fulfilled by chickens, but rather poorly by turkeys. Furthermore, the correlation of combined weight of breast and leg muscles to the remainder of the starved live weight tends to be rather low for turkeys but of a high order for chickens. As a consequence total body weight can but rarely be a reliable measure of the weight of flesh which is present on the individual turkey, and hence the deviation of the observed from the calculated body weight cannot with certainty be expected to measure the relative degree of fleshing.

It is a misfortune that the fleshing index, though satisfactory for Barred Rocks, should be suited to estimation of fleshing in only one of the breeds of turkeys examined herein. In the absence of such precise information, selection of desirable fleshing type must rely on its subjective evaluation as presented in each individual.

## CONCLUSION

Breeds, such as the Broad Breasted and the Beltsville Small White and the female sex in general, which have the roundest and most fleshy breasts have relatively the deepest keels. On the other hand the Standard Bronze males which have the same average torso depth as the Broad Breasted males are typically slabsided because of their deficiency and thinness of breast musculature. At the same time their keel is proportionately quite low. However, within breeds, the relatively shallowest torso is associated with roundness of breast conformation.

Birds of a flying habit such as turkeys and pheasants have a greater proportion of breast muscle to leg muscle than is found in walking species such as the chickens. At the same time the former have a proportionately much deeper keel than the latter.

The average ratio of muscular tissue to the remainder of starved live body weight increases from breed to breed as their mean weight of body increases. However, this relationship does not hold between individuals within the various breeds.

Turkeys are proportionate to their body weight, shorter in the legs than chickens. The heavy breeds are proportionately shortest in leg and the female leg shorter than that of the male.

Determination of fleshing by the fleshing index was accomplished with the same critical accuracy for Beltsville Small White turkeys as had previously been obtained for chickens. This was not the case for three other breeds of turkeys. The reasons for this have been discussed.

## ACKNOWLEDGMENT

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## BOOK REVIEW

LECTURES ON THE INORGANIC NUTRITION OF PLANTS. By D. R. Hoaglund, Professor of Plant Nutrition, University of California, 177 pages, 44 text figures, 28 plates; published by The Chronica Botanica Co., Waltham, Mass., U.S.A.; Wm. Dawson Subscription Agency, Ltd., Toronto, Ont. 1944. Price. $4.00.

The question of plant nutrition is such a broad one, involving so many different aspects, that a general survey of the subject presented in a condensed form is of great value. This has been accomplished in the publication by Professor Hoaglund which embraces the material of seven lectures, revised and supplemented, presented at Harvard University under the Prather Lectureship.

In the preface, the author says, "Obviously, this small volume cannot have any of the characteristics of a monograph or of a text. Its purpose is to present a general perspective of several important aspects of the field of plant nutrition, with a broad interpretation of the term in mind. . . . . The limited scope of the lectures precluded consideration of a vast number of important contributions to the field surveyed."

In Lecture 1, a survey of the problems of plant nutrition is presented. The author comments "I doubt that there exists in any other system presented for scientific or practical study a comparable degree of complexity." Problems of the soil solution in relation to plant nutrition, the rôle of soil colloids, soil acidity and alkalinity in relation to plant growth, experiments by artificial culture methods, and climatic influences are some of the questions considered as an introduction.

The functions of micronutrient chemical elements in plant growth are taken up in the second lecture. Special attention is given to experiments in connection with studies on zinc. Some practical aspects of micronutrient problems are presented, with reference to animal as well as plant nutrition.

Lectures 3 and 4 cover the absorption and accumulation of salts by plant cells, and the upward movement and distribution of inorganic solutes in the plant in their relation to transpiration and to plant metabolism. The use of radioactive isotopes in following the movement of ions, and the importance of this relatively new method of investigation, are discussed. Although considerable work has been done, the present knowledge of salt movement in the plant is still inadequate.

The growth of plants in artificial media in relation to the study of plant nutrition is discussed in Lecture 5. Conditions for the growth of plants in artificial culture are given and the effect of aeration of nutrient solutions and of climatic factors on the growth of plants is presented.

Several aspects of the problems of chemical processes occurring in plant tissues as salt is moving into and through the cells are presented in Lecture 6. These include the buffer action within the plant which keeps

the hydrogen ion concentration within narrow limits, the relationship of organic acids to salt absorption, and metabolism and protein formation in relation to absorption of nitrogen. The author contends the biochemical attacks on plant nutrition will constitute one of the strongest trends of the future. Finally, in Lecture 7, certain aspects of the potassium nutrition of plants are given as illustrating problems of the system soil-plant-atmosphere.

The author has taken his illustrations largely from the work of the California scientists with which he is familiar. Plates and figures are used freely to illustrate the points discussed, and references are given to about 150 published articles. The book has apparently well fulfilled its purpose of presenting a general view of the field of plant nutrition.

H. J. ATKINSON.